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"Application and Verification of the Visual Soil Assessment method for pastoral grazing (according to SHEPHERD, 2009) in Kyrgyzstan under the given specific site conditions"

Thesis in the study program: Integrated Natural Resource Management

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Declaration of Originality

I hereby declare, that the present thesis "Application and Verification of the Visual Soil Assessment method for pastoral grazing (according to SHEPHERD, 2009) in Kyrgyzstan under the given specific site conditions" and the work reported herein have not been submitted as a part of any other examination procedure and has been independently written. All passages, including those from the internet, which were used directly or in modified form, especially those sources using text, graphs, charts or pictures, are indicated as such. I realize, that an infringement of these principles which would amount to either an attempt of deception or deceit will lead to the institution of proceedings against myself.

Berlin, 10.01.2015 Peter Kirch

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List of abbreviations

BD	– Bulk Density
C_{org}	– Organic Carbon
CORINE	– Coordination of Information on the Environment
DIN	– Deutsche Industrie Norm (german industrial norm)
DM	– Dry Matter
FAO	– Food and Agriculture Organisation
GDP	– Growth Domestic Product
GIZ	– Gesellschaft für Internationale Zusammenarbeit
ha	– Hectar
K_{sat}	– Saturated Hydraulic Conductivity
KA5	– Bodenkundliche Kartieranleitung – 5. verbesserte und erweiterte Auflage (Pedological mapping guidelines – 5. edition)
LADA	– Land Degradation Assessment in Drylands
MODIS	– Moderate Resolution Imaging Spectroradiometer
MPR	– Maximum Penetration Resistance
MSDI	– Montana Spatial Data Infrastructure
MSQR	– Müncheberg Soil Quality Rating
NDVI	– Normalized Difference Vegetation Index
nFK	– Nutzbare Feldkapazität (Usable Field Capacity)
NGO	– Non Governmental Organisation
PAW	– Plant Available Water
PDI	– Pasture Degradation Index
PESERA	– Pan-European Soil Erosion Risk Assessment
PPI	– Plant Performance Index
PQA	– Plant Quality Assessment
PWP	– Permanent Wilting Point
RUSLE	– Revised Universal Soil Loss Equation
SEI	– Susceptibility to Erosion-Index
SOM	– Soil Organic Matter
SQA	– Soil Quality Assessment
SQI	– Soil Quality Index
UK	– United Kingdom

UNESCO – United Nations Educational, Scientific and Cultural Organization
UNEP – United Nations Environment Programme
UPAGES – Utilization and protection of agricultural ecosystems in Central Asian high mountains – case study Kyrgyz alpine pastures
USSR – Union of Soviet Socialist Republics
USLE – Universal Soil Loss Equation
VDLUFA – Verband Deutscher Landwirtschaflicher Untersuchungs- und Forschungsanstalten (Association of german agricultural research institutes
VESS – Visual Evaluation of Soil Structure
VSA – Visual Soil Assessment

All not listed abbreviations are units of the international system of units (SI) or extended SI units.

Technical note concerning transcription

The Cyrillic letters of the Russian language are transcripted by the "English transliteration" according to the New Encyclopaedia Britannica (1997), Volume 22. Some words used in the text have their origin in the Kyrgzy langugae. These words are, whenever possible, romanized according to the romanization system of the United States Board on Geographic Names / Permanent Committee on Geographical Names for British Offcial Use (BGS/PCGN 1979 System).

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1 Introduction

In the beginning of the 21st century global trends in population growth and globalisation of the economy with its capitalistic tendencies are leading to an increased demand of natural resources and are putting high pressure on the global ecosystem. The induced changes in the ecosystem are already perceivable and measurable and are widely interpreted as not favorable for human life.

These aspects are hold true in the agricultural sector, which serves as the main food basis for the human population. The pressure on natural resources and the ecosystems caused by the agricultural sector comes mainly from the use of natural resources, such as soil and water, in the agricultural production process. The induced changes are many, and often lead to a reduction in productivity and sustainability of the effected resources and ecosystems. Keeping in mind the key role, which this sector plays for human life, the importance of changing the currently applied production processes to achieve a sustainable resource use is emphasized. This is crucial to ensure sufficient agricultural production also in the future.

One form of agricultural production is the keeping of livestock, which on a global scale, is based largely on the usage of pastures. In this form of livestock production, the natural resource "pasture" serves as a livestock fodder basis. Possible consequences to the resource due to its feeding usage are e.g. changes in the vegetation patterns or in the soil quality. The specific outcomes always depend on the degree of pressure, which is in turn mainly dependent on the stocking rate and the specific site conditions. Through a high degree of pressure, which is often referred to as "overgrazing", land degradation processes can be induced. The connected short term effects are e.g. a reduction in biomass productivity and a decline of palatable species. In the long term, the overall quality of the grazing land is reduced and processes like soil erosion and biodiversity loss are likely to occur. To allow for sufficient long term agricultural production on pastures, while avoiding land degradation, a sustainable concept of pasture usage is needed which is adapted individually on the site specific conditions.

In the Central Asian region, where the world’s largest contiguous areas of grazed land are situated (BUSSLER, 2010), livestock keeping has been practiced since a very long time and was traditionally connected to a nomadic lifestyle. This is also true for livestock keeping in Kyrgyzstan. In the past 90 years the pasture management system in Kyrgyzstan has twice undergone dramatic changes. Both changes were induced by changes in the political system in the country. In the late 1920s the Kyrgyz areas were incorporated into the USSR. This political development also implemented transformation processes in the agricultural sector: the traditional system was replaced by a state-controlled production system, which was characterized by large production units (Kolkhoz) and high stocking rates. In the beginning of the 1990s this production system ended with the breakdown of the USSR and a market based economy with a profit oriented production system was implemented. During the transission process, it came to a breakdown of livestock numbers, but rather to a relocation of the grazing pressure then to a reduction. In recent years an additional nationwide trend of increasing total livestock numbers can be observed, as it is the single possibility for many people to maintain their income from livestock raising (BUSSLER, 2010). The pressure on the natural resource "pasture" is therefore increasing, which implies also an increase of unfavourable changes in the ecosystem. It is now necessary in a global, national and local context to develop a sustainable pasture management system to allow for a protection of the ecosystems and to ensure a sufficient agricultural production also in the future.

1.1 Objectives

This master thesis was written in the framework of the project "Utilisation and protection of agricultural ecosystems in Central Asian high mountains – case study Kyrgyz alpine pastures" (UPAGES), which aims "to facilitate productive utilisation and at the same time [allow for] an efficient protection of pastures" (KAUFMANN et al., 2010, p. 15). For the realisation of the project goals natural scientific and socio-economic factors are evaluated and taken into account, as a concept for sustainable pasture usage is developed. For the necessary field research a representative project region in Kyrgyzstan is chosen and analysed concerning different parameters (climate, vegetation, soil, production), which are relevant for the development of a sustainable pasture management system (KAUFMANN et al., 2010).

One part of the development approach is the application and verification of the visual soil assessment method (VSA) for pastoral grazing (according to SHEPHERD, 2009) under the given site specific conditions in Kyrgyzstan. The process of applying and verifying the VSA is conducted to make a first step towards the provision of a suitable, reliable and defensible visual site assessment method under the given site specific conditions. The importance of the success of this process is emphasized, as such a method would allow the land users themselves to analyse the pasture in use. Such a direct application ensures that the land user would be directly involved in the evaluation process and would consequently have a direct access to the results. Both is supposed to lead to a sensitisation concerning the topics "soil and pasture degradation" and to an awareness concerning the need of a sustainable utilisation of the pasture areas.

The main research question posed in the context of this work is:

Is the Visual Soil Assessment method for pastoral grazing (according to SHEPHERD, 2009) fully applicable under the given specific site conditions in Kyrgyzstan?

To answer this question the VSA method is applied and verified in the research area to:

- assess the applicability of the VSA method under the site-specific conditions in Kyrgyzstan,
- verify the correspondence of the VSA indicator results to the actual site conditions,
- verify the overall indicator composition.

The hypothesis is that the VSA method, developed for pastures in New Zealand (SHEPHERD, 2009), is also suitable for the application in Kyrgyzstan, which is underpinned by the statement of SHEPHERD et al. (2003b) that "the VSA can (therefore) be used by farmers regardless of where they are and what their [regarded] soil types (are)" (p. 115).

The assessment process consists of the application of the VSA method in different pasture usage regimes and also of the application of two additional field methods of visual site assessment. The latter is conducted to test the applicability of possible alternative indicator sets. The additionally performed visual methods are the Müncheberg Soil Quality Rating (MSQR) and a method described in „Monitoring Manual for Summer Pastures in the Greater Caucasus in Azerbaijan" (ETZOLD, 2010) (this method will be referred to in the further reading as "Method according to Etzold").

Furthermore standard field and laboratory-based methods for the assessment of soil and vegetation data, like the measurement of soil resistance to penetration, the water infiltration measurement and the determination of the standing biomass are applied in order to create a site related reference data pool. The reference data pool is needed to be able to determinate in how far the obtained VSA results corresponded with other measured site conditions. In cases of repeated disparity between the different data sets, a need for the adaptation of the VSA method (either regarding the reference description or the method composition) to the specific site conditions is indicated.

To approximate the answer to the leading research question, in the first part of the work the study area is described and characterised. Information on the topics climate, bedrock and relief, soils, water, flora and fauna, land use and land use problems are presented in detail. In the following part the choice and the functioning of all applied field and laboratory methods is explained. This includes explanation concerning the theory and the practical application of the applied method. In the chapter "Results" the outcomes of the field research are summarised. The chapter also includes the presentation of calculated correlations between the different results.

In the end of the thesis an answer to the above stated research question is given and discussed. A synthesis of the findings and a proposal for further research concludes the work.

1.2 Limitations of the Study

The thesis has its limitations, as all presented results refer to a specific research area. Furthermore the assessment was carried out in the rather short time period of four month and only two repetitions of the conducted assessments could be performed. Due to these facts, the statistical significance is limited and a transfer of the findings to areas outside the research area should be done carefully, considering that e.g. topographical, micro-climatical and land use parameters are to a certain extent specific to the chosen area.

2 State of the art

The description given by KAUFMANN et al. (2010) of the UPAGES project, which is the greater framework of this master thesis, contains the basic information regarding the topic "pasture degradation in Kyrgyzstan". In the following chapter additional information shall be given on the topics "land and pasture degradation", "pasture degradation in Kyrgyzstan" and on methods used to assess pasture degradation. The latter is also linked with information on the method choice and the applied research approach.

2.1 Land and Pasture Degradation

For the Central Asia region, with its mountainous topography and the predominant semi-arid climate, there is an overall high risk of the occurrence of land degradation processes (JI, 2008). In general terms "land degradation" was defined by the FAO in 1979 as "a process, which lowers the current and/or potential capability of soils to produce (quantitatively and/or qualitatively)". In this context the term "land" includes the aspects of flora, fauna, soil, water, geomorphology and relief, and the term "produce" refers to the production of animal or plant products (VAN LYNDEN, G, 2012). In a more recent definition, given by the Land Degradation Assessment in Drylands (LADA, 2008), a group of the United Nations Environment Program (UNEP), land degradation is specified as "the reduction in the capacity of the land to provide ecosystem goods and services and assure its functions over a period of time for its beneficiaries" (VAN LYNDEN, 2012, p 7). This definition will be referred to, when the term "land degradation" will used in the following (for further literature on the topic see file "Literature on the topic land degradation" on the CD).

Overall, these rather broad definitions already predict that there are also manifold ways to judge or to classify the degree of land degradation. This is supported by the fact that until now no uniform international method for the classification of land degradation exists (DREGNE, 1998). Also KAPALANGA (2008) states that "there are plenty of different approaches for assessing land degradation worldwide", which may be based on "expert opinions, field measurements, field observations, land user's opinions, productivity changes and remote sensing and modelling methods" (KAPALANGA, 2008, p. 17) to assess land degradation at different levels (see also chapter 2.2). Therefore numerical estimations and information on the topic have to be evaluated considering the assessment method used, as no standardised method is agreed upon. This is also true for information on land degradation for the land use form "pasture", as it can vary significantly depending on the assessment method applied (ROBINSON et al., 2003).

In Kyrgyzstan 49 % (93.650 km²) of the total land area is used as permanent pasture, which is equivalent to 87 % of the total agriculture area (FITZHERBERT, 2006). Even though pastoralism has a long tradition in Kyrgyzstan, many livestock owners have little experience with commercial stock management practices (BUSSLER, 2010). This is because the pasture management system changed significantly in the course of the country's history (see chapter 3.1.6). After the soviet centrally planned usage of pastures and intensive livestock breeding, a post-independence period followed, which was/is characterised by a "hodgepodge" of government regulatory entities and practices, which [was/is] brought about by intended and unintended policy changes in the rural sector" (UNDELAND, 2014, p. 7). Consequently, a mismanagement of grassland areas can be observed, which causes severe problems. One of them is pasture degradation. As indicated above, specific information on the topic may vary significantly, depending on the chosen reference indicator. This is shown in the following examples, which shall depict the condition of the pastures in Kyrgyzstan: According to FITZHERBERT (2006) an estimated area of more than 45.000 km² is already affected by erosion processes, which is about half of the total pasture area. In contrast, according to a report by the US Aid organisation, 25.000 km² (27 % of the total pasture area) are littered with inedible weeds, 17.000 km² (19 % of the total pasture area) are eroded, and 30.000 km² (33 % of the total pasture area) are substantially degraded (USAID, 2013). Further estimates can be found in (BUSSLER, 2010), (KAUFMANN et al., 2010) and (WORLDBANK, 2007). Despite the various ways of determining the actual degree of land/pasture degradation and the manifold existing information on the topic, also with regards to the multiple reference indicators, an overall high relevance for Kyrgyzstan can be acknowledged.

2.2 Assessment methods for land and pasture degradation

As stated above, there is a wide range of assessment methods to determine the conditions of land, and thus also to classify the factual degree of land degradation. According to KAPALANGA (2008) the high variety of methods is mainly due to the complexity of the topic of "land degradation", the fact that evidence for land degradation differs from area to area, and that it also depends on the subject emphasized (e.g. land use, nature protection). In table 1 a summary is given of a selection of methods in use, which are grouped according to the units/system they assess (e.g. global or national level).

Despite the fact that none of the methods can be regarded as "standard method" for a certain level of application, the literature review showed that some common factors can be made out for all approaches reviewed: Even though focusing on different indicators (e.g. biological, physical or chemical), assessments of the general state of the soil condition and/or the plant condition are part of all reviewed approaches. Furthermore the evaluation of the assessed data is always based on one of the two following principles:

The first principle is to classify the assessed data and to compare it then with data of a modelled "ideal situation"(see DREGNE et al., 1992).The second principle is to monitor certain soil or plant parameters over a defined time and to judge the degree of degradation through the determination of a development trend. According to DREGNE et al. (1998) the second principle is to be preferred, as it is based on a broader, more reliable data set, even though no common time interval for the repeated assessments is defined.

In context of the conducted work an evaluation of pastures/grassland on the "local and field/farm level" with a special focus on the aspect of the soil condition was performed.

Through the term "soil condition" the "ability of soil to ... (provide) a habitat for soil biota, nutrient cycling, water retention and primary plant production" (DE GROOT et al., 2002, p. 395) is described. To directly measure the condition of soil is difficult though, "because it is a product of numerous different physical and chemical attributes and processes" (CHAPMAN et al., 2011, p. X). Therefore the measurement is often performed through "the examination of the soil profile", which "has been a standard technique for many soil scientists" and "is widely used in pedology, soil surveys and land evaluation as well as for soil management (BOIZARD et al., 2005, p. 4).

Table 1: Summary of possible assessment methods of land degradation (KAPALANGA, 2008, edited by KIRCH, 2014)

Units/Systems assessed		**Methods used**	**What was assessed**	**Units / values**
Global Level	Full Cover Analysis Partial cover (soils/ rangelands/ agricultural lands/ drylands, etc.)	**Experts opinion** (e.g. indicators, questionnaires, etc.) **Remote sensing and GIS** (e.g. mapping)	Land/soil degradation: (severity, degree, extent) Soil (erosion, fertility, productivity, etc.) Vegetation change Biodiversity loss	%, Classes (1,2,3,4,5 - light – very severe / excellent – very poor, etc.), t/ha/yr
Regional level	Drylands, rangelands, grasslands, forests, deserts, etc., Soils, Rivers systems, etc.	**Expert opinion** (e.g. indicators, questionnaires, interviews, focus groups, etc..) **Remote Sensing and GIS** (e.g. NDVI, MODIS, etc.) **Modelling** (e.g CORINE, PESERA erosion models, etc.) (mainly for croplands) **Field monitoring and measurements** (measurements to verify models) -pilot areas **Grid System Monitoring (EU)**	Land/soil degradation: - severity, degree, extent, impact, causes, & risks - Soils (erosion, fertility, productivity, etc.) Vegetation change Land cover Land uses Slopes Climate (rainfall, temperature) for modelling Biodiversity loss Landscapes/ Ecosystem function	%, Classes (1,2,3,4,5 for light – very severe / excellent – very poor, etc..), t/ha/yr
National level	Lands (agricultural lands, grasslands, forests, conserved area, deserts, etc.), Soils, Rivers, Rangelands systems	**Expert opinion** (e.g. indicators, questionnaires, interviews, focus groups ect.) **Land users opinion** (e.g. indicators, etc.) **Remote Sensing and GIS** (e.g. NDVI, MODIS, MSDI ect.) **Modelling** (e.g CORINE, PESERA models, etc.) **Field monitoring and measurements** (measurements to verify models) - pilot areas	Land/soil degradation: - severity, degree, extent, impact, causes, & risky - Soil (erosion, fertility, productivity, etc.) Vegetation change Land cover Biodiversity loss Land uses Rangeland health/conditions, Climate (rainfall, temperature), etc	%, Classes (1,2,3,4,5 for light – very severe; extremely health – extremely unhealthy, etc.), t/ha/yr Frequency of indicators
Local and Field/Farm level	Lands (cropland lands, grasslands, forests, conserved area, deserts etc.), Soils, Rivers, Rangelands, etc.	**Expert opinion** (e.g. indicators, questionnaires, interviews, focus groups, etc.) **Land users opinion** (e.g. indicators etc.) **Remote Sensing and GIS** (e.g. NDVI, MODIS, MSDI ect.) **Modelling** (e.g USLE/RUSLE, CORINE, PESERA models, etc.) **Field monitoring and measurements** (verify models) - farm plots **Estimates of productivity changes**	Land/soil degradation: - severity, degree, extent, impact, causes, & risks;, Soil erosion (Sediment yields) Rangelands Health/ condition Soil condition (quality, salinity, stability, fertility, etc.), Crop yield & suitability, Soil condition, Landscape/ ecosystem function, Land cover, Biodiversity loss, Land uses, Climate (rainfall, temperature), etc	%, Classes (1,2,3,4,5 for light – very severe; extremely health – extremely unhealthy, etc.), t/ha/yr Frequency of indicators

In the report "Visual Soil Structure Assessment" (2005) by BOIZARD et al. (2005) a wide range of "new" assessment methods is presented. Some presented methods, like the "Whole profile assessment", the "SOILpak method" or "Le profil cultural" still rely on the assessment of a whole profile and require therefore "a considerable knowledge of pedology and time to do in the field" (GUIMARAES et al., 2013, p. 92) as they also take the intrinsic soil quality into account. Other methods, like the "Visual Soil Assessment" or the "Peerlkamp score" simplify the assessment of the soil condition, as these methods are focused only on the topsoil (first 30 cm) and aim to assess "only" the effects of cropping systems on the soil condition.

Possible effects on the soil condition that mainly occur in the land use form "pasture" are generated through (selective) feeding and trampling (EVANS, 1998), especially if over usage occurs. Primarily effects concern not only the soil, but also the vegetation, which is discussed in a broad spectrum of literature. Regarding the topic "vegetation", results of pasture over usage are found to be a reduction in the vegetation cover (THAMSBORG et al., 1996, EVANS, 1998) and root structures (ZHOU et al., 2010), a change in the vegetation composition (BUSSLER, 2010) and a reduction of soil cover through vegetative litter (ABRIL and BUCHER, 2001, in PEI et al., 2010).

Regarding the direct effects on the soil condition, it has been reported that high stocking rates lead to an increase in soil compaction and in soil density (PEI et al., 2010), while soil aggregate stability is reduced (RUSSEL et al. in SYNMAN et al., 2005). These changes caused by livestock are often restricted to shallow surface depths (0-150 mm) (MAFF, 1970 in NEWELL-PRICE et al., 2013), making the "simplified" assessment methods (and therefore also the VSA method) seem highly suitable to assess them well. All changes combined lead to a decrease in soil fertility, to a lower infiltration rate and to an increase in erosion of topsoil (SYNMAN et al., 2005), and finally to a "permanent degradation of land productivity and [to a] destruction of the ecosystem" (PEI et al., 2010, p. 34). It has to be noted though that the specific outcomes of all listed causing factors are always dependent on the particular vegetation and soil properties of the regarded pasture unit, and may therefore differ in severeness from unit to unit (ZHOU et al., 2010).

The assessment of the soil condition is important also in the context of land/pasture degradation, as the obtained information can be used as a basis for the development of an adapted land management system. The land management system is the key element of a sustainable land use in general, as "a failure to manage land in accordance with its capability risks degradation of resources both on and off site, leads to a decline in natural ecosystem values, agricultural productivity and infrastructure functionality" (GRAY et al., 2011, p. 1). The chosen VSA method is described as "the "road map" to better farm and environmental management" (SHEPHERD, 2009, p. 5), which in turn is the envisaged goal of the UPAGES project. The method version for pastoral grazing is mainly focused on the examination and evaluation of the soil condition, but it also includes the assessment of the plant condition. Hence, a VSA site evaluation is based on the assessment of ten soil and plant indicators respectively. The results of the VSA site assessment allow for both above presented general site evaluation principles: A single assessment can be compared with ideal results, but it is as well possible to perform assessments over a period of time to allow the determination of a development trend.

In MUELLER et al. (2012) the VSA method is characterised as fitting on the local scale for monitoring and controlling and is evaluated as "very reliable" (MUELLER et al., 2012, p. 80). During the research conducted by MUELLER et al. the VSA method was applied at 20 locations in different agricultural regions during the past eight years. Most locations were chosen in Germany, Russia and Northern China, but some locations were also found in New Zealand, Canada, UK and Denmark (MUELLER et al., 2012). Furthermore SHEPHERD (2003a) states that the VSA method was carried out at 91 sites on 40 soil types under dairying, dry stock farming, cropping, indigenous and exotic forestry covering a range of soil types from different parent materials, climate, topography, and under different land uses and management practices in New Zealand. The results of these applications were closely related to a key number of measured soil properties, such as dry aggregate-size distribution, saturated hydraulic conductivity (Ksat) and air permeability (SHEPHERD, 2003a). Therefore Shepherd comes to the conclusion that "the close relationships between visual scores and laboratory-based measures of soil properties show that VSA provides a reliable and defensible semi-quantitative method to assess some key soil characteristics" (SHEPHERD et al., 2003a, p. 163).

Nevertheless, many authors have stressed the importance of verifying the visual methods through other site-specific information as well, such as on soil physical quality as doubts persist about the validity of applicability under any site condition. For example, the visual evaluations of soil structure and whether is it equally valid in soils of different textures" is questioned in GUIMARAES et al. (2013). And KAPALANGA (2008) also states that in order to obtain representable results, "methods or techniques need to be critically selected, taking into account their suitability, applicability and adaptability to local conditions" (KAPALANGA, 2008, p. 17).

In general, the validation of visual methods has been the topic of many recent studies. Reviewing these studies, two principle approaches for the method validation could be made out: On the one hand the results of the visual methods were verified through a correlation with measured physical and chemical soil parameters. In the study of NEWELL-PRICE et al. (2013) e.g. besides the visual method also the following measurements were carried out to characterise the nature of the soil condition: cone penetrometer tests, shear vane tests, soil bulk density measurements, gravimetric soil water content, soil organic carbon and particle size distribution. In ASKARI et al. (2013) "soil physical and chemical properties were determined that reflect soil structural quality in order to evaluate the VESS (visual) method" (p. 4). Besides the named measurements, also the total porosity, the dry aggregate stability, the total nitrogen- and total carbon-content were also assessed in this study. A similar approach can be found in GUIMARAES et al. (2013).

On the other hand a cross-check of the results of different visual methods can be performed to verify the visual soil evaluation. Examples of this validation approach can be found in BOIZARD et al. (2005) and in MUELLER et al. (2013).

The two principle approaches were found to be reasonable and relevant. Therefore aspects of both approaches were considered during the method choice.

3 Material and Methods

3.1 Material

In this subchapter a rather general description of the natural and socio-economic conditions in Kyrgyzstan (in literature also often referred to as the Kyrgyz Republic) will be followed by a presentation of more detailed facts about the respecting conditions in the chosen research area.

3.1.1 Location

Kyrgyzstan, located between the latitudes 39° and 44° N, and the longitudes 69° and 81° E, is a landlocked country in Central Asia. The country's total area of 199.951 km^2 covers mostly the central-northern part of the Tian-Shan (also spelled Tien Shan) mountain range (see figure 1). Therefore, about 94 % of the total area is situated above 1.000 m a.s.l. (FITZHERBERT, 2006).

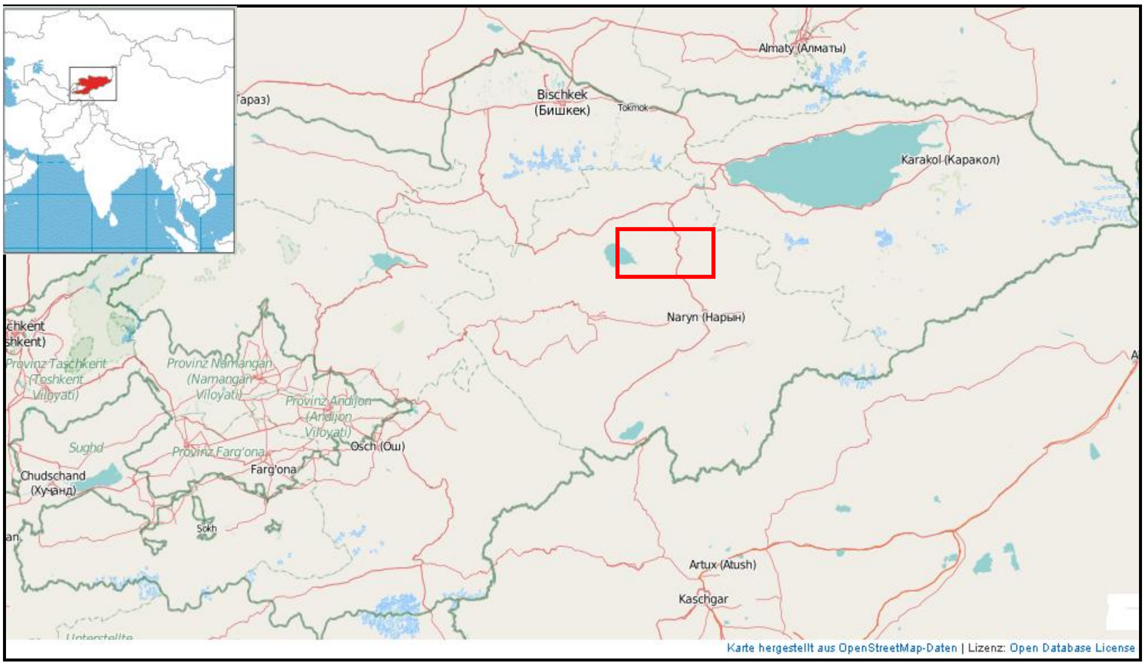

Figure 1: Geographical location of the research area, indicated through the red box (Openstreetmap, 2015, edited by KIRCH, 2015)

The total population of the country was 5.7 Mio. people in the year 2013, which implies a population density of 28,5 inhabitants per km² (WORLDBANK, 2014). The region in which the field research was conducted belongs to the Naryn Oblast (KAUFMANN et al., 2010). This Oblast is situated approximately 250 km southeast of the kyrgyz capital

Bishkek and has an area of 45.200 km². With a population of about 270.000 people, averaging to 6 inhabitants/km², the Oblast is one of the least populated areas in the country (FAO AQUASTAT, 2014). In the centre of the Oblast (see figure 1) the Raion Naryn (formerly named Raion Tyan-Shan) is located.

The research areas were chosen in this Raion. It was selected because it shows a high natural variability and all of the most common kyrgyz species of livestock are present here (KAUFMANN et al., 2010). Furthermore, the typical problems of pasture overgrazing are very urgent in this region, which can be seized easily by visual observation. As indicated in the map below the field research was conducted in three different pasture management units in the Raion (see figure 2). The pasture management units differed in so far, that the units "Tesyk" and "Karatal" were primarily used as winter pasture (in some parts these units are even used the whole year around). In contrast to that, the pasture management unit "Sary Dzhel", located above 2.900 m, was primarily used as a summer pasture (in kyrghiz: "Dschailoo") and is therefore in the text referred to as "Tesyk summer pasture".

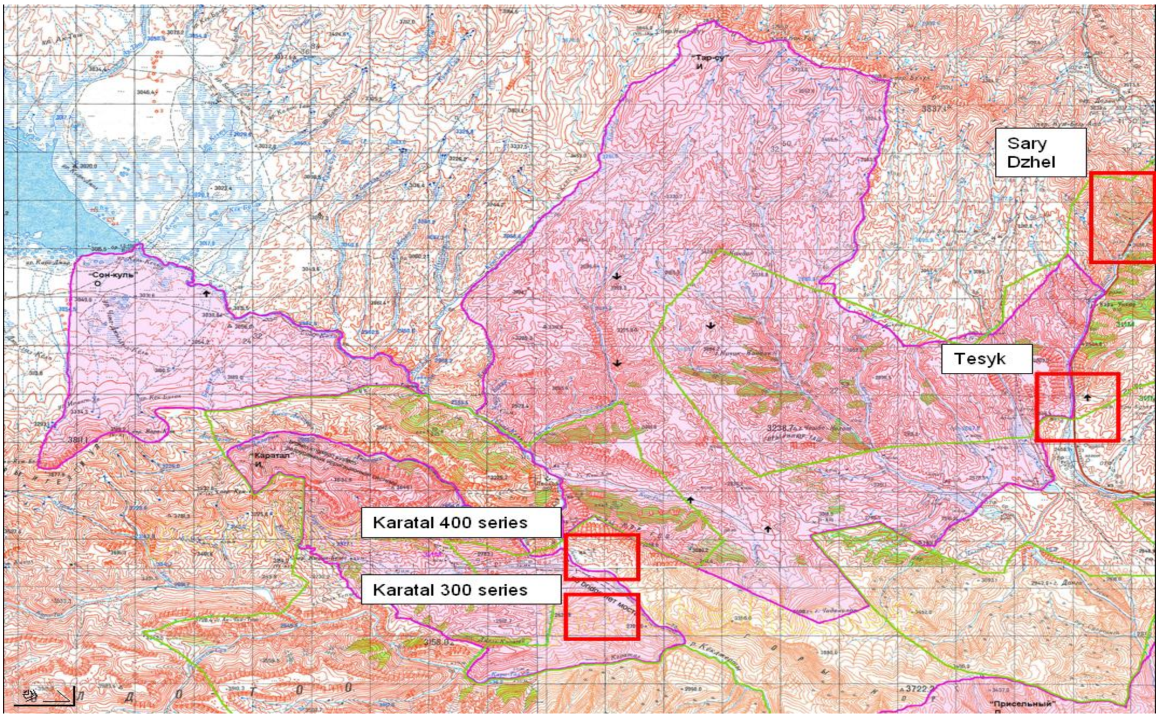

Figure 2: Map of the research area (modeled by KIRCH, 2013)

Detailed maps and pictures, which show the location of the research area and the predominant site conditions can be found on the CD in the file Maps and pictures of the research sites".

3.1.2 Climate

The macro-climate of Kyrgyzstan can be described as a cold semi-arid to warm continental climate according to the Köppen–Geiger climate classification. Hot and dry summers, cold winters and an overall precipitation maximum during the summer months are characteristic for these climate zones (KOTTEK et al., 2006). Absolute temperatures in Kyrgyzstan vary from minus 54 °C in winter to 43 °C in summer and the average annual precipitation is estimated to 533 mm (FAO AQUASTAT, 2014). These macro-climate features are mainly determined by the geographical position and "the interaction between the south-western branch of the Siberian anticyclonic circulation and a cyclonic activity in the west" (AIZEN et al., 1997, p 1394).

The meso-climate is manifold and mainly determined by the orography of the Tian-Shan mountain range and of the surrounding Pamiro-Alai and the Pamir mountain ranges. The given orography prevents a high air mass flow from the South, whereas from the North air can move freely into the area (WEISCHET et al., 2000). This leads e.g. to different precipitation regimes, which can be divided into four different main regions: western, northern, central, and eastern Tian Shan. In northern and north-western regions the precipitation is generally higher and reaches up to 1000 mm per year (GOTTSCHLING, 1996). In contrast to that the central and the eastern region are much drier. Mainly depending on the elevation, the annual precipitation reaches between 200 mm to 900 mm, with a maximum during the summer period (GOTTSCHLING, 1996). In general, with increasing heights (m a.s.l.) an increase in total precipitation can be observed. However, not only the precipitation changes with the elevation: also temperature, variation in temperature, humidity, and frequency of frost and intensity of solar radiation are influenced through increasing heights (m a.s.l.). In combination with the variance in these parameters due to the different geographical expositions, the altitudinal zoning leads to a tessellated character of the climate in Kyrgyzstan on a micro climatic scale (GOTTSCHLING, 1996).The tessellated character of the climate can also be observed in the research area. The climate in the research area is mainly influenced "by mountain ridges confining the region from every direction and also by a substantial elevation above sea level", leading to a dry and extreme continental climate" (CHINGAJOEV, 1997, p. 271). As stated above, it can be also noted, that in dependence on elevation, exposure and slope steepness a high variety of micro climatic conditions can be found in the research area. This is shown through the data of the temperature and precipitation regime of the Naryn District. For the temperature regime "a large difference between the coldest and warmest annual temperature (range of annual air temperature) of 70-82°C (depending strongly on the elevation)" (ASHLEY et al., 2012) is characteristic. The precipitation regime, with an overall low annual precipitation ranging from 178 to 320 mm, is "strongly influenced by the mountain topography [...] and not strongly correlated with elevation [...] as northwestern slopes intercept the dominant moist air flow" (ASHLEY et al. 2012).

3.1.3 Geology

The geology in Kyrgyzstan is strongly dominated by the characteristics of the Tian Shan. The Tian Shan is a "large intraplate mountain system, about 1.500 km long and up to 500 km wide that formed between the Tarim Basin and the Kazakh Shield, as a result of the India-Asian collision" (STROM et al., 2006, p. 125). The uplifting of the mountain range started in the late Cretaceous and is still on going with an average elevation rate of 31,9 m/Ma since the starting of the tertiary (GOTTSCHLING, 2006).
The central Tian Shan displays a basin-and-range topography caused by distributed reverse faulting and folding. The resulting, generally east west trending, ranges are several tens of km long, 5–20 km wide, and 4,5–5,5 km high and define blocks, composed of previously deformed Paleozoic rocks (THOMPSON, 2002).
The ranges "are separated by wide lenticular or narrow, linear intermountain depressions. These contain Neogene and Quaternary deposits, mainly sandstone, siltstone with gypsum interbeds, and conglomerates." (STROM et al., 2006). This current surface structure was strongly influenced during the last glacial period. A resulting characteristic is the high amount of area with a slope steeper than 20°. The areas with such a characteristic represent 55 % of the total area of Kyrgyzstan and are therefore the dominant topographical feature of the country (GOTTSCHLING, 1996).
Nowadays "due to fluctuations in temperature and moisture, processes of chemical and physical weathering are active" (FRANZ, 1973, p. 456). Especially in steep areas, slope forming processes and mass movements occur and the related accumulative landforms, like talus cones are visible (FRANZ, 2012). Typical features of the topography of the research area are "ridge slopes, which are cut by various gorges which ramify and create a complicated system of small ravines" (CHINGAJOEV, 1997, p. 172). Measured slope steepness reached up to 80 %.

3.1.4 Soils

For the territory of Kyrgyzstan a "great diversity of soil cover and various levels of soil fertility are characteristic" (DZUNUSOVA, 2008, p. 9). The determining factors for this diversity are the given multiple topographic features (like elevation, exposition and slope) and the manifold climatic conditions (differing in e.g. in temperature, moisture and seasonal variation). According to the FAO/UNESCO classification, the following major soil units formed under the given conditions: Calcic Xerosols in the Ferghana Valley; Calcaric Gleysols in the Chui Valley and Xerosols in the Naryn Oblast and in the central highlands. In the mountain areas "Lithosols and outcrops of rock debris occur while the plateau-like surfaces are characterised by Yermosols, especially Takyric Yermosols" (FITZHERBERT, 2006).

A widespread characteristic for all the named soils is the presence of a loess cover. Mostly depending on the exposition, the thickness of this cover can vary between several centimetres to 1-2 m, with the highest values being measured on northwards exposed slopes (GOTTSCHLING, 2006).

Information on soils in Kyrgyzstan can also be found according to the national classification system of MAMYTOV (1974). MAMYTOV elaborated a soil classification system for Kyrgyzstan, which relates to the classification system of the former Soviet Union. According to MAMYTOV, an elaboration of a specific classification system for Kyrgyzstan was necessary as "the soils of Kyrgyzstan are not comparable to other soils in the other regions of the world"[1] (GOTTSCHLING, 2006, p. 40).

According to the respective "Soil map of Kyrgyzstan SSR" (see file "MAMYTOV soils in Kyrgyzstan" on the CD), soils in the territory of Kyrgyzstan are grouped as follows: (i) soils of foothill slopes and foothills (from 500 m to 2.000 m); (ii) soils of intermountain hollows (from 1.300 m to 3.200 m); (iii) soils of hilly mountains (from 3.000 m to 4.000 m); (iv) soils of mountain slopes (from 1.000 m to 5.000 m) (also see file "MAMYTOV soils in Kyrgyzstan" on the CD). According to this classification the study region does not show a high diversity of soils. The present soils are all part of the group "soils of mountain slopes" (почвы гроных склонов) and range from the so called dark Burosem soils to cryo histosols and mineral cryosols (MAMYTOV et al., in

[1] Original text: "Dabei wird die besondere Eigenständigkeit der Böden Kirgisistans und die fehlende Vergleichbarkeit mit Böden anderer Regionen insbesondere der Tieflandsbereiche betont."

KAUFMANN et al. 2010). According to the world reference base (2014) the present soils are: Kastanozem (dark and light), Calcisol and Solonetz.

3.1.5 Flora and fauna

The above described features of the climate and the topography of Kyrgyzstan, and the presented soil and water properties are determining factors for the composition of the flora and fauna of the country. Overall, a high diversity can be named as main characteristic, which is a result of the manifold habitats caused by the different combinations of microclimates and landscape types. The country is "occupying only 0,13 % of all lands of the planet, but presents huge biodiversity – 1 % of biodiversity of the planet" (DZUNUSOVA, 2008, p. 7). The habitats include "desert land, open steppe, high grasslands, broadleaf and coniferous forest, alpine ecosystems and a variety of aquatic habitats: wetlands, perennial and intermittent streams, rivers, fresh and saline lakes, including Lake Issyk-kul" (FITZHERBERT, 2006, p. 14).

The flora is composed of boreal, indo-himalaycal, Tibetan, Mongolian, and other floral elements, which combined make up 7.723 plant species, of which about 3.760 are higher flowering plant species (DZUNUSOVA, 2008 and GOLOVKOVA 1990, according to GOTTSCHLING 1996). Endemic plants among vegetative organisms make up 233 species in total or 3 % of all plant species growing in Kyrgyzstan (DZUNUSOVA, 2008).

According to FITZHERBERT (2006) a classification of the flora preformed according to the different elevation levels results in three major habitat groups: i) below 1.500 m a.s.l.: historically dominated by grass steppe, with marshes and reed-beds along rivers. In areas of higher precipitation relictic ancient fruit and nut forests occur; ii) between 1.500 and 3.000 m a.s.l.: mainly open mountain grasslands and scrub, with some broadleaf and conifer forest; iii) above 3.000 m a.s.l.: alpine grassland and sub-alpine meadows, intercalated with permanent snowfields, glaciers and rocks.

The species diversity of the fauna is also naturally high, with e.g. over 500 species of vertebrates (including 83 mammals), of which many species are also endemic either to Kyrgyzstan or to Central Asia (FITZHERBERT, 2006).

As the research area is located in the inner/central Tian Shan, overall typical central Asiatic flora elements are characteristic (SOBOLEV in GOTTSCHLING, 2006). It can be furthermore stated that the mountain relief causes a pronounced vertical zonal pattern: "With height a more mesophilic steppe, meadow forest complexes, subalpine and alpine meadow steppes replace the semi desert landscape typical for elevated mountains" (CHINGAJOEV, 1997, p. 172).

3.1.6 Land use

The main land use form in Kyrgyzstan is agriculture, occupying an area of 107.286 km² (equivalent to 55,9 % of the land area) and providing 20 % of the nation's GDP (WORLDSTAT, 2014). Other land use forms of minor importance are built environments (such as settlements) and forest areas, which will not be further discussed in this chapter.

The total agricultural area can be divided into meadows/pastures (93.752 km², equivalent to 87,4 % of agricultural land), arable land (12.800 km², equivalent to 11,9 % of the agricultural area) and land occupied by permanent crops (734 km², equivalent to 0,7 % of the agricultural area) (WORLDSTAT, 2014). The arable land areas and the areas with permanent crops are mainly located in the southern regions, including Osh province and Jalalabad province in the Fergane Valley, in the northern Chuy and Talas valleys and in the Issyk Kul basin (DZUNUSOVA, 2008). In contrast to that, meadows and pastures can be found all over the country, most of them located in the Naryn Oblast and in the Issyk-Kul and Chui regions. The pasture areas are accounted for as "a source of great wealth in Kyrgyzstan" (BAIKAGUSHEV, 2011, p. 104).

Regarding "pastures", a brief description of the actual state will be given in the following, as this land use form is predominate in the research area and of vital importance for the UPAGES project and also for the thesis at hand. The description will start with a short historical overview:

In general, the history of the land use form "pasture" can be divided into three distinctive periods: (i) the period of traditional herding patterns prior to collectivisation in the Soviet era ("Pre-Soviet" period, until the 1930's); (ii) the period of soviet centrally planned usage of pastures and intensive livestock breeding (until the beginning of the 1990's); and (iii) the post-independence period with new government regulatory entities and practices brought about by intended and unintended policy changes in the rural sector (UNDELAND, 2014). Characteristics of the first period are the "extensive and highly mobile migratory livestock production without strictly defined borders, which took advantage of seasonal changes in the natural vegetation and seems not to have let to overgrazing" (VAN VEEN et al., in BUSSLER, 2010, p. 10). The second period was characterised by a forced collectivisation and a drastic livestock production increase, which was made possible through state organised livestock transport and winter fodder supplies from other Soviet states (BUSSLER, 2010). Nevertheless, with more than 11 Mio. sheep in the country, "pastures experienced an excessive load due to over-grazing"(BAIKAGUSHEV, 2011, p. 106).

As the third period started with the collapse of the USSR-wide system of fodder provision and livestock transport, consequently the break down and partitioning of the collective farming structures is characteristic for the beginning of this period (UNDELAND, 2014). The executed land reforms and the predominant poor socio-economic situation let to an enormous reduction of livestock number and to a decline of structured use of pasture land (BUSSLER, 2010). The latter is shown through an imbalance between the intensive usage of pastures near settlements and outlying (remote) pastures, as livestock owners were not able to use remote pastures "due to a lack of transportation and funds" for the transhumance (BAIKAGUSHEV, 2011, p. 110).

In recent years there has been a newly increase in total livestock numbers. This because "keeping [of] livestock is crucial for the rural population as cattle, horses and small ruminants do not only provide families with food but they does also serve as a saving" (KAUFMANN et al., 2010, p. 12). As this quote already emphasis, the actual situation is mainly characterised by a concentration of livestock almost exclusively in household plots and peasant farms (MUNAVAR, 2011).

As these structures developed under the pre-setting of a market-based economy, they are "based on the use of resources available at low or very low costs, and are driven by access to feed-resources with minimum or non-investment" (MUNAVAR, 2011, p. 4).

In order to develop an appropriate management plan of pastures on national level, a legal framework concerning land use, the "law on pastures", was adopted in the year 2009 and is since then being implemented by the Ministry for Agriculture (CIS LEGISLATION, 2014).

A central aspect of the framework is the formation of local pasture committees, which are being put in charge of the development and the implementation of a local pasture management plan for a respective land area (GIZ, 2014). This work also includes the control and registration of the livestock numbers (BAIKAGUSHEV, 2011). To ensure a professional execution of the task, the work process is being accompanied by specialised NGOs, like the "Camp Alatoo" organisation (for additional information on this NGO see the file "CAMP ALATOO" on the CD). By the end of 2011, 454 user committees were set up across all of the country’s rural communities (GIZ, 2014).

Furthermore "a unified map of the borders of pastures in Kyrgyzstan is being developed, to facilitate the development of pasture management plans" (BAIKAGUSHEV, 2011, p. 114). In the research area a user committee already exist, which is in charge of the pasture management process.

A short summery of the whole presented development in the pasturing sector can be found table 14 (see chapter "Annexes"), where effects on the ecology of the pastures are also listed.

3.1.7 Land use problems

Taking the information given in the preceding subchapters into account, it can be concluded that the regional natural circumstances put limits to land use in Kyrgyzstan.

The climate and the topography, and in recent years an increase in degraded land area, are especially concerning the agricultural sector and are holding back the agricultural productivity. For irrigated areas mostly water-logging, salinisation, and pollution from agricultural chemicals lead to land degradation (MACLEAN, 2011). For the pasture areas, where degradation processes have already been documented during the Soviet era, the estimation of degradation depends on the pasture category and the assessment method applied (see chapter 2). According to the Kyrgyz legislation, there are various classification of pastures possible: 1) according to the geographical location and the distance to the next settlement, 2) according to the activities conducted on the pastures, 3) according to the jurisdiction and 4) according to the seasonal use (UNDELAND, 2005). The last listed classification approach is the most commonly used one. In accordance to this approach the overall pasture resource can be divided into three categories: (i) winter pastures (occupying 23 % of the total pasture area), which are generally located close to permanent settlements in areas of light or negligible snowfall; (ii) summer pastures (occupying 45 % of the total pasture area), which are characterised by a high productivity and are located in middle to high mountains, at significant distance from the settlements; and (iii) spring-autumn pastures, (occupying 32 % of the total pasture area), which are usually located in the foot hills below 2.500 m a.s.l. and are usually used for grazing in the early spring or serving as first natural feeding source after winter.

Over time, with the changes presented in chapter 3.1.6, the intensity of usage of the different pasture types has changed. In contrast to the pre-Soviet era, during which no land use problems are reported, the pasture management during the Soviet era led to first land use problems. As stated in WORLDBANK (2007, p. 56): "The objective of maximising livestock production overshadowed that of sustainable use of pasture resources, and supplemental winter feeding was not an adequate tool to prevent overgrazing and pasture degradation." This can be proofed by various datasets of the State Land Management and Design Institute (Giprozem) and the Kyrgyz Land Management Institute (Kyrgyzgiprozem). The data shown in table 2, evaluated by the Giprozem, indicates that the dry matter production in Kyrgyzstan (measured in kg DM/ha) overall declined during the soviet era (1930s until early 1990s) and even kept declining in the post-Soviet era.

Table 2: Average pasture dry matter production (kg/ha) since 1948 (WORLDBANK, 2007)

Observation Period	Average yields for the Republic	Type of Pasture including		
		Spring-Autumn	Summer	Winter
1948 – 1955	285	270	335	170
1969 – 1978	260	225	330	160
1980 – 1985	215	195	285	115
1986 – 1994	220	210	275	135
1997 – 2004	210	170	275	85

According to this data set, especially affected areas were the winter pastures (50 % decline) and the spring-autumn pastures (37 % decline). The data of the Kyrgyz Land Management Institute (Kyrgyzgiprozem) differs slightly, but indicates a comparable trend for the Soviet era.

As stated in chapter 3.1.6, the beginning of the post-Soviet area was characterised by a strong decline in livestock numbers, which led also to an overall lower fodder demand. This decline did not fully solve the land use problems associated with grazing though, because the simultaneously upcoming lack of transport and funds implied new pasture usage patterns. As the livestock was consequently maintained close to the settlements, high pressure on the winter and spring-autumn pastures were caused, while a huge amount of the remote pastureland was not being used at all.

This situation is still widely prevailing today. BAIKAGUSHEV (2011) states that the imbalanced placement of livestock on winter and respectively spring-autumn pastures leads to further degradation in these areas. In their paper SHIGAEAVA et al. 2007 stress the effect of the current pasture usage regime on the summer pastures: According to them, ecological assessment have shown that compared to the data from 1978 an increase of 5 to 22 % in forage productivity in summer pasture areas occurred.

3.2 Methods

The task of the application and verification of the VSA method was realised on five sites, which belong to two different pasture management units (see chapter 3.1.1). Besides the VSA method two other field methods of visual site assessment were conducted on these pasture sites to test possible alternative indicator sets. The applied visual methods were the Müncheberg Soil Quality rating (MSQR) by MUELLER (2007) and a method described in „Monitoring Manual for Summer Pastures in the Greater Caucasus in Azerbaijan" by ETZOLD (2010). These methods were chosen on the basis of a literature research, which was conducted with the aim to find methods, which are similar to the VSA method. The key criteria for the choice were:

- The method is indicator based,
- The assessment can be fully conducted in the field,
- Only a small amount of equipment is needed for the field assessment.

The above named field methods fulfill all three criteria.

Besides the visual field methods also standard field measurements and laboratory-based analyses were conducted on the chosen pasture units. In these cases, the leading selection criterion was "simplicity", both in the field equipment needed and in the associated field application process. This was essential due to the expected transportation and working conditions on site. Soil related parameters were evaluated through the measurement of soil resistance to penetration, water infiltration rate and soil core sample determination. These measurements are also "proposed to be used as possible standard components of frameworks for assessing the functional status of grasslands by uniform methodologies over Eurasia." (MUELLER, 2014, p. 200). With the help of the obtained results, the overall soil condition was supposed to be described and possible pasture degradation indications, like e.g. "soil compaction", which "is evidenced by a coarsening or loss of soil structural units, increase in bulk density, decrease in porosity (particularly macro-porosity) and a reduction in hydraulic conductivity of the soil (i.e. reduced water infiltration)" (NEWELL-PRICE et al. 2013, pp. 66) were supposed to be identified. Additionally, soil indicators like the soil colour and the rooting depth were evaluated using the Munsell colour chart and the "Bodenkundliche Kartierunganleitung" (KA5).

Plant related parameters were also evaluated through methods described in the KA5, but also through a repeated measurement of the vegetative dry matter production, the "Klapp-Stählin" and the "Braun-Blanquet" method. The choice of these methods took the expected field conditions (e.g. limited infrastructure for the transport of material and samples) and the research limitations (e.g. field assessment time) of the UPAGES framework into account. All field assessment methods and field measurements were conducted twice during the research period.

After a detailed description of the VSA method, a brief description of the two additional visual field methods is given in the following subchapters. Information will be presented on their main characteristics and also on their practical application in the field. Besides the detailed descriptions of all above listed field measurements and laboratory-based methods, a brief summary of their application in the field and the associated sample and data processing follows. In the end of the chapter it is presented how the collected data was analysed and interpreted. In table 4, which is also to be found in the end of the chapter, all assessed parameters are summarized.

3.2.1 Visual Soil Assessment method

The VSA was developed "to provide a simple, standardised method that anyone can use to assess and monitor soil quality and plant performance quickly and cheaply. It therefore uses dynamic indicators of soil quality that are capable of changing under different management regimes and land use pressures" (BOIZARD et al., 2005, p. 20). As a result the VSA provides a semi-quantitative measure that equally takes soil and plant properties into account (SHEPHERD et al., 2000). The basic idea of the VSA is standardised for all different kinds of land use forms. However, the method can also be adapted to account for special features of the analysed land use form (e.g. pastoral grazing, annual crops) (BIOAGRINOMICS, 2013).

The VSA assessment should be carried out at least on four different sample sites to allow an assessment of an area of five hectares, if the analysed area is reasonable homogenous (BOIZARD, 2005). If the assessed area is not homogenous a division of the area in homogeneous management units needs to be fulfilled to allow for representative assessment results. Before carrying out the actual VSA assessment the soil moisture of the analysed site should be tested. This test can be conducted without measuring instruments: if the soil can be rolled to a 40 mm long and 7-10 mm thick worm without cracks (depending on the soil type), the soil is too wet for testing (see figure 3 below).

Figure 3: The possible result of a "worm test"

This information, as well as further general information (e.g. GPS reference data on the sample site location, seasonal weather) about the analysed site is to be noted on a scorecard. In the case of a positive result of the worm test, the actual assessment of the soil and plant indicators follows. Regarding the soil properties, a set of ten indicators is used, which can be assessed on site without knowing the history of the pasture (SHEPHERD, 2003b). The score of the different indicators is obtained by comparing an aspect of the actual soil/site condition with three reference pictures and descriptions given in the VSA guide for each indicator respectively. Each picture and description corresponds to a certain condition of the analysed indicator and is equivalent to a score between 0 (bad condition), 1 (moderate condition) and 2 (good condition). The respective assessment procedure for each indicator is shortly presented below.

After the above shown soil moisture test, the actual site assessment starts with the topsoil examination. For the topsoil examination (e.g. soil texture, soil structure) initially a hole of about 200 mm x 200 mm wide and by 300 mm deep is made. In the case of a homogenous topsoil, the sample to determine the soil texture can be taken in whatever depth between 0 and 300 mm. Otherwise the sampling procedure is either performed in the upper or in the lower layer. The soil texture is assessed by estimating the percentages of sand, silt and clay by feel (SHEPHERD, 2003b). A soil texture diagram and descriptions given in the field guide can be used as reference.

In accordance with the result of the soil texture assessment the determination of the soil structure is performed. To determine the soil structure the "drop shatter"-test is conducted. During this test a sample cube of 200 mm is dropped onto a wooden board. The dropping height can vary between 0,5 m and 1 m and a maximum repetition of three times is possible, all depending on the identified soil texture. The resulting broken up sample is sorted by fraction size of its aggregates. The final soil structure score represents the ratio of big to small aggregates. During the sorting process the amount of earthworms in the sample is also to be counted, as the knowledge of the total earth worm number in the sample cube allows the direct estimation of the indicator "earthworms".

For the estimation of the soil porosity, an additional slice of soil (approximately 100 mm wide, 150 mm long and 200 mm deep) is taken from the sample hole and is then to be broken in half. The resulting fresh surface should be compared with the reference descriptions and pictures. This procedure allows at the same time the estimation of the indicator "number and colour of the present soil mottles".

In contrast to that the estimation of the soil colour is not picture related. An additional moist soil sample from a protected area (e.g. under a fence line) nearby is to serve as estimation reference. The actual estimation is therefore a result of the comparison between the two soil colours under consideration of the descriptions in the field guide.

Another topsoil sample cube of 100 mm, which has again to be taken from the initial sample hole, is used for the assessment of the indicator soil smell. After the dig out the cube is broken in half and the fresh surface is placed close to the nose. Regarding the descriptions given in the field guide, the smell is scored.

For the estimation of the potential rooting depths the sample hole has to be profounded to the depth, where a root growth limiting soil layer or other root restricting factors occur. The scoring of the rooting depth is performed according to a linear distributed scale between 200 mm and deeper than 800 mm.

In contrast to the already presented indicators, the indicators "surface ponding" and "surface relief" are evaluated without direct reference to the sample hole. In both cases the area surrounding the actual sample site is being looked at during specific time periods. For the indicator "surface ponding" the disappearance of water should be observed after a wet period during the autumn, the spring and the summer season. The indicator "surface relief" is supposed to be assessed at the end of the winter season. The smoothness of the terrain is to be judged visually.

The schema for the assessment of the plant indicators is identical to the assessment of the soil indicators. A set of ten indicators has to be evaluated in order to obtain a final score. Nevertheless, in contrast to the soil indicator set, the assessment of the plant indicators requires additional knowledge of the immediate paddock history to receive a representative final score (SHEPHERD, 2003b).

The first plant indicator is called "pasture quality". The amount of green grass leaf, legume and dead matter, plus the botanical composition of the sample site are to be compared with the reference descriptions and pictures. A percentage chart is given in the field guide, which shows how much area is corresponded to a specific percentage amount (e.g. of legume cover) given in the field guide. An additional measurement of the "sugar content of the pasture during the middle part of a sunny day using a simple refractometer" (SHEPHERD, 2009, p. 34) is recommended to obtain a further reference value. Closely related to this indicator are the estimations of the indicators "weeds" and "area of bare ground". Both indicator are also assessed with the help of the percentage chart. Their indicator scores represent how much of the area sampled is either covered with weeds or not covered at all.

The plant indicator "clover nodules" requires again digging, as the number of nodules on clover roots is to be counted. Important for the scoring of this indicator is not only the number of clover nodules, but also their size and their inside colour, as well as the depth in which they occur. To a maximum depth of 250 mm the roots of three to four clover plants are to be excavated. The number of root nodules is assessed relative to the root length (average number of nodules per 20 mm root length).

Digging is also required to estimate the indicator "root length and root density". A soil pedon of 200 mm x 200 mm and 300 mm depth taken next to the initial soil sample site serves as basis for the assessment. The root system present within this soil pedon is to be exposed with the help of a knife or by gentle shaking (SHEPHERD, 2009), and to be compared with the pictures given in the field guide.

For the estimation of the indicator "pasture colour and growth relative to urine patches" the assessment time should be chosen just before the next grazing period begins. The reference pictures given in the field guide indicate the gradation in colour contrast between areas of the urine patches and the rest of the pasture. The same assessment time is preferably chosen for the evaluation of the indicator "pasture growth". It is to be evaluated how much vegetative dry matter grows per ha and year. A repeated measurement, with the help of a rising plate or herbage cut, performed regularly at the same time of the year can serve as basis.

An areal evaluation is also necessary for the estimation of the indicators, "pasture utilisation" and "drought stress". The indicator "pasture utilisation" was designed to measure how uniformly the pasture was used during the last grazing period. In order to obtain a representable result, the assessment time should be chosen close to the end or

shortly after the grazing period. For the assessment of the indicator "drought stress" besides the aspect of areal evaluation also the timing is of high importance, as a moment after a prolonged dry period is to be chosen. In cases of a limited timeframe for the assessment, alternatively the knowledge of local farmers can serve as evaluation basis.
The main aspect of the indicator "production costs" is the answer to the question "whether overall production costs have increased in order to maintain stock-carrying capacity" (SHEPHERD, 2009, p. 66). The knowledge of the local farmers and statistical data collected over several years are to serve as basis for the evaluation of the indictor.
After the above described field work and the notation of all obtained results on the soil-/plant score cards, the calculation of the final scores follows. To obtain the final scores, the so-called "Soil Quality Index" (SQI) and the "Plant Performance Index" (PPI), all weighted indicator scores are added. The preceding weighing is performed through the multiplication of each obtained indicator score with a specific weighting factor between 1 and 3. Through this a specific importance is assigned to each indicator. A list of all soil and plant indicators, including the weighting factors can be found on the CD (file "VSA method for pastures"). The scores (each of them out of a maximum of 50 points) indicate the overall soil and plant performance at each site. To simplify the interpretation of the numerical results, the results can in transformed with the help of a reference table into the "Soil Quality Assessment" (SQA) and the "Plant Quality Assessment" (PQA), which can take on the categories: "good", "moderate", "poor".
The results should be looked at separately and then be compared. This allows the identification of discrepancy between the soil condition and the condition of the plants. In the case when the SQI score is significantly higher than the PPI score it can be suggested that the full productive potential of the soil is not being realised. In the contrasting situation, when the PPI is significantly higher than the SQI, a high fertiliser input to counter the detrimental effects of poor soil quality on production is indicated.

For the application of the method in the field the following equipment is needed:

- Spade to dig out a 20 cm cube of soil,
- Plastic basin (45x35x25 cm),
- Hard board (26x26x1,8 cm),
- Heavy duty plastic bag (75x50 cm),
- Knife and tape measure,
- Water bottle,

- VSA Field Guide,
- Pad of score cards,
- Magnifying glass,
- Brixmeter.

For an individual with experience, the assessment of the soil indicators should take about 20 minutes and the assessment of the plant indicators takes another 5–10 minutes per site (SHEPHERD, 2009).

3.2.2 Muencheberg Soil Quality Rating

The Muencheberg Soil Quality Rating (MSQR) is a method for "assessing soil quality of farmland in the field" (MUELLER et al., 2007). The assessment refers to the current condition of a soil pedon including the medium term soil hydrological-, thermal-, geological- and terrain conditions and the human impact (MUELLER et al., 2012), which are all so called "soil forming factors". As stated in MUELLER et al. (2012), "the current approach is restricted to the [assessment] of the soil's suitability for cropping and grazing [...] with a focus on rainfed cropping in temperate zones [...]"(p. 5). For grassland the ratings assume "a minimum level of accessibility and management [...]" (MUELLER et al., 2007, p. 5). The result of this indicator-based assessment method is a semi-quantitative measure, which can be interpreted as a rough estimate of the local crop yield potential.

The assessment covers aspects of soil texture, soil structure, topography and climate and is based on eight basic indicators and thirteen hazard indicators (MUELLER et al., 2012). These indicators take inherent and dynamic agricultural soil quality into account and are listed in figure 4 below.

The overall method procedure will only be shorty described in the following as it is closely related to the procedure of the VSA method described in chapter 3.2.1.

The first step of a site assessment according to the MSQR is the digging of a soil pit of about 20 cm x 30 cm x 40 cm. In order to recognise the soil layering or a shallow water table, an auger of about 7 cm diameter should also be drilled from the bottom of the pit down to a depth of 1,6 m (MUELLER et al., 2012). The sample site and the surrounding area is then examined in a very similar way as described in chapter 3.2.1. The rating of each indicator is performed on the basis of the visual appraisal of a certain aspect in reference to the specific descriptions and/or illustrations in the MSQR field manual. In this field manual descriptions, tables with thresholds and illustrations are given according to which the different indicators can be classified. In order to take the importance of certain soil qualities into account the field manual also provides specific weighting factors for each indicator and for each of the land use forms "arable land" and "grassland" respectively.

Basic indicators	Hazard indicators
1. Substrate (3) 2. A horizon depth (1) 3. Topsoil structure (1) 4. Subsoil compaction 5. Rooting depth (3) 6. Profile available water (3) 7. Wetness and ponding 8. Slope and relief (2) (in brackets: indicator specific weighting factor)	1) Contamination 2) Salinisation 3) Sodification 4) Acidification 5) Low total nutrient status 6) Soil depth above hard rock 7) Drought 8) Flooding and extreme waterlogging 9) Steep slope 10)Rock at the surface 11) High percentage of coarse soil texture fragments 12) Unsuitable soil thermal regime 13) Miscellaneous hazards

Figure 4: Indicators of the MSQR method

Through adding up of the weighted indicators scores a basic soil score is calculated in a first step. In a second step the soil hazard indicators are scored also in reference to the specific descriptions and/or illustrations in the MSQR field guide. By following the "results of final rating", which are also given in the field guide, a multiplier can be calculated on the basis of the obtained hazard indicator scores. Through the multiplication of this factor with the basic soil score the final soil score can be obtained. The overall final soil score can range between 0 and 100, where 0 is the worst possible result (very poor soil quality) and 100 is the best possible result (very good soil quality). For the assessment in the field the following equipment is needed:

- Tools (spade, borer, foot rule, knife, field guide),
- Munsell colour chart,
- Photo camera,
- GPS,
- VSA equipment (see chapter 3.2.1),

- Additionally the following equipment can be useful, but is not necessarily needed: hydrochloric acid, measuring device for pH and electrical conductivity.

As "the method requires some experience in estimating soil texture class and organic matter content" (MUELLER et al., 2012, p. 8) it is mainly designed for extension workers and for experienced soil scientists. Just as the VSA method, the MSQR should be carried out when the soils are moist and/or suitable for grazing.

3.2.3 Method according to Etzold

The method described in the monitoring manual for summer pastures "is designed for a comprehensive and objective monitoring of pasture condition development on the basis of scientific knowledge" (ETZOLD et al., 2010, p. 1). The manual is separated into three parts in which the main tasks of the methods are described. These main tasks are:

- Assessing the pasture management system (via interview),
- Assessing the pasture condition,
- Giving management recommendations.

Their fulfillment is supposed to follow the specifications given in the flowchart below (see figure 5).

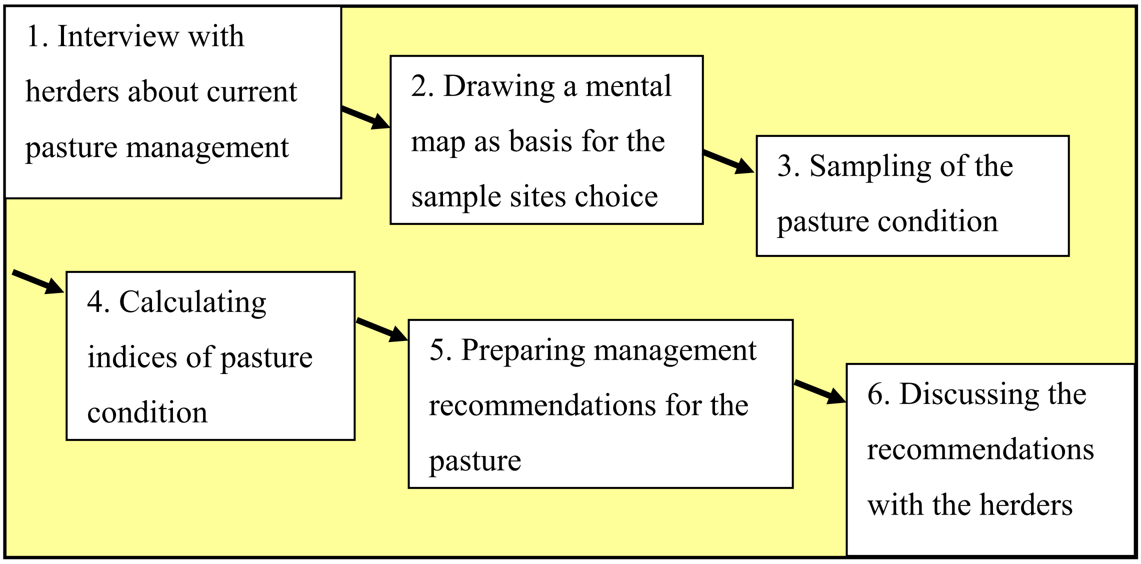

Figure 5: Overview of the separate tasks of the method according to Etzold

In order to serve as a reference source for the VSA method (as intended in this thesis) only the tasks 2, 3 and 4 needed to be fulfilled. The task 2 is based on a preferential sampling design and starts with the separation of the pastures in homogeneous management units. These units are then assessed on the basis of representative sample areas, which are called plots. The plots are supposed to have a dimension of 10 m x 10 m and should be representative for a circle with a minimum radius of 50 m (ETZOLD et al., 2010). A data sheet with all parameters, which are needed to describe the plot condition, is given in the field manual. In general, information on the geographical situation, the soil, the vegetation, the extent of erosion and the visual appraisal of the state of the pasture is demanded. For further details all parameters (coloured in light blue) can found in table 4 (see page 54).

With a certain routine the assessment time in the field is supposed to take one hour and the following equipment is needed (ETZOLD et al., 2010):

- Clipboard for the data sheets and pen,
- Rain clothes and/or an umbrella,
- GPS,
- Inclinometer,
- Compass,
- Folding rule or a measuring tape,
- Mechanical counter ("counting clock"),
- Digital camera.

From the obtained field data indicator scores can be derived with the help of the indicator-specific scoring tables (see (ETZOLD et al., 2010). The "Susceptibility to Erosion-Index" (SEI) and the "Pasture Degradation-Index" (PDI) are then calculated on the basis of the indicator scores. The SEI reflects the potential erosion on a site and the PDI reflects the current state of the pasture site (ETZOLD et al., 2010). For the calculation of the index values the obtained data is converted into a weighted value system. For each variable a table is given in which the collected data value is correlated with a weighted value of 0 to 60 (ETZOLD et al., 2010). Through the adding up of the weighted values the different index values are obtained.

In the manual "a repetition of the assessment at the same site after a certain time (e.g. every 2 years), [...] with the identical set of methods" is advised (ETZOLD et al., 2010, p. 2).

3.2.4 Soil Core Sampler

The Soil Core Sampler was used to take the samples for the determination of the bulk density (BD) of the soil at the assessed sample sites. The BD according to HERNANZ et al. "is the single most useful parameter of soil physical structure", as "it is a direct

measure of soil compaction (or loosening) and is essential to assess total available pore space within a soil" (HERNANZ et al. in MERRINGTON, 2006, p. 35).
The instrument was applied according descriptions in the German DIN standard 18125-2. The method described in the DIN standard can be used when the soil is cohesive and does not have a high content of coarse material. Furthermore, non-cohesive soils with high middle- to fine-sand fractions can be sampled (MOELLER, 2007).
According to the DIN standard the sample cylinder is driven into the soil by hammering. Once the cylinder is completely filled with undisturbed soil it is carefully removed. The cylinder has then to be cleaned on the outside and to be carefully closed, so that no moisture can evaporate. The latter allows the additional determination of the soil moisture content and the C_{org} content of the sample taken.

3.2.5 Penetrometer

The penetrometer was used to determine the resistance to vertical penetration of the soil in the closely surroundings of the assessed sample site. This measurement was conducted with a hand held penetrometer for static penetration tests (the 06.01.SA penetrometer produced by Eijkelkamp). The instrument allows for an indicative measurement of the maximal resistance to penetration from 0 up to 1.000 N, with a maximum accuracy of +/- 8 % in the advised measuring range of 200 to 700 N (EIJKELKAMP, 2013).
The principle component of the measuring device is a manometer with a maximum pointer, which is connected to a plunger equipped with handgrips. To the plunger the rods are attached, which hold the penetration cone. The length of the rod as well as the diameter of the penetration cone are variable. The selection of the penetration cone is dependent on the expected penetration resistance of the soil. For expected high penetration resistance values a small cone diameter is to be chosen, while for low values the larger cone diameters are to be applied. It has to be kept in mind, that the larger the cone the more accurate the value of the resistance to penetration can be determined (EIJKELKAMP, 2013).
The main factors influencing the measurement are soil density, soil texture, moisture status and temperature (KIRKHAM, 2004; EIJKELKAMP, 2013). Regarding the soil moisture status, the most important influencing factor, it can be generally stated, that with "increasing soil water content the penetration resistance decreases" (KIRKHAM, 2004, p. 122). Regarding soil texture, especially in soils containing high amounts of coarse material, difficulties often occur to obtain consistent and reliable penetrometer

measurements, especially with increasing penetration depth (KIRKHAM, 2004). Changes in temperature, if above freezing, do not lead to detectable differences in soil resistance. For temperatures below 5 °C deviations between repeated measurements may occur though, as a result of the thickening of the oil in the measuring device (EIJKELKAMP, 2013).

In the field, after the cone selection, the actual measurement is conducted through the vertical introduction of the cone into the soil at a steady rate of 2 cm/sec. The resistance values to penetration are measured and recorded in Newton (N). According to MUELLER (2014), the "data values obtained [...] are normally distributed over a number of measurements, and the number of replications at a single point can thus be relatively low" (p. 202). Through the division of the recorded values by the cone surface area the penetration resistance value (N/cm^2) is obtained, which is an indicator for the bearing capacity of the soil. Furthermore compacted layers in the soil can be traced on the basis of this data (NEWELL-PRICE et al. 2013), which have high influence on the growing circumstances of the flora in situ (EIJKELKAMP, 2013).

The method offers the advantages of being relatively "straightforward, rapid and inexpensive and [it] has the potential to provide information at a range of depths with relative ease" (NEWELL-PRICE et al. 2013, pp. 66). Disadvantages of the method include the variation of penetration resistance values with changing soil water-, soil organic matter- and soil texture (coarse material)-content and differences in insertion rate and in friction forces on the shaft (CAMPBELL and O'SLLVIAN, 1991 in NEWELL-PRICE et al. 2013, pp. 66).

3.2.6 Mini Disk Infiltrometer

A Mini Disk Infiltrometer is a tension infiltrometer, which is designed to measure the infiltration rate and the unsaturated hydraulic conductivity of a medium placed on (DECAGON DEVICES, 2012). The Mini Disk Infiltrometer used during the field research was produced by Decagon Devices (Pullman, Washington). Its principle component is a 32,7 cm long, in two chambers divided, plastic tube. The upper chamber of the tube is closed by a rubber devise, in which an additional air-inlet tube is integrated. The lower chamber, which is marked with a gradation from 0 to 100 ml on the transparent tube walls, is closed at the base with a porous sintered stainless steel disk (see figure 6). This chamber serves as a reservoir for the water which is to be infiltrated into the soil. The actual infiltration is realised through the porous sintered stainless steel disk, which allows the water to infiltrate into the soil, but not to leak out into the open air (DECAGON DEVICES, 2012). Through the regulation of the air-inlet tube, the water tension and thus the suction at the disc surface (often also referred to as "pressure head") can be controlled. The application of a water tension at the disc surface leads to the exclusion of macro-pores during the infiltration and flow process, as the pore diameter is proportional to the matric potential of a pore (with smaller pores having a higher matric potential). In cases when the matric potential of a pore is lower than the water tension at the disk, water will not infiltrate into this pore. Through this the so called "preferential flow" (flow through macro-pores) is prevented. This is an important difference in comparison to other infiltration measurement methods such as the double ring method, where water infiltration takes place under ponded (saturated) conditions. The Mini disk infiltrometer therefore allows a better assessment of the infiltration processes of e.g. rain into an unsaturated soil zone (KIRKHAM, 2004). For the infiltrometer to work in the field, a vegetation-free spot has to be chosen (if not available, vegetation should be scraped away from the soil) at which good contact between the infiltrometer and the undisturbed soil surface is given. The latter has to be regarded, if the rainfall acceptance rate is of primary interest. If the crust is removed a better estimate of the conductivity of the underlying A horizon will be given (COUGHLAN et al., 2002).

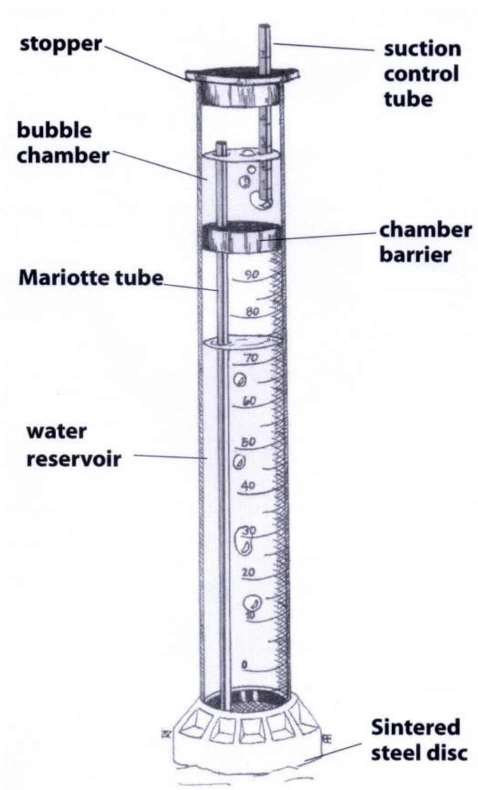

Figure 6: Infiltrometer diagram, (DECAGON DEVICES, 2012)

A thin layer of contact sand can be put between infiltration disk and the soil surface to improve the contact (DECAGON DEVICES, 2012). Before the placement of the devices, both chambers have to be filled with water. The actual measurement is conducted by recording the time interval during which a minimum of 15 to 20 ml of water infiltrates into the soil (DECAGON DEVICES, 2012). The cumulative infiltration, which is the total quantity of water which infiltrated into the soil, and the infiltration rate, which "may be defined as the meters per unit time of water entering into the soil regardless of the types or values of forces or gradients" (KIRKHAM, 2004, p. 145), can be derived from the data obtained. Both indices are affected by the water sorptivity and water conductivity of the specific soil type, as water entry into soil is caused by matric and gravitational forces. The matric forces depend on multiple influencing variables, which can be categorized as event-dependent and event-independent variables. Examples of the first category are the soil moisture content or the slaking of the soil surface. Event independent variables are e.g. the content and decomposition degree of the organic substance and the soil structure (SCHACK-KIRCHNER, 2006).
Taking these aspects into account, the resulting cumulative infiltration can be calculated in dependence of the time with the formula according to PHILIP (1957):

$$I= s\, t^{1/2} + k_{\theta}\, t$$

with
I= cumulative infiltration [cm],
s = sorptivity [cm*s$^{-1/2}$],
t = infiltration duration [s],
k_{θ} = hydraulic conductivity as a function of the water content q [cm*s^{-1}].

The formula describes "the process of one-dimensional infiltration in which water is assumed to flow vertically (or more rarely horizontally) into the soil" (KIRKHAM, 2004, p. 150). The first term of the formula describes the gravity-free absorption into a ponded soil due to capillarity and adsorption and the second term represents the infiltration due to the downward force of gravity. In general, the formula describes the phenomena, that the soil sorptivity has a big effect on the overall infiltration rate in the beginning of the measurement, but losses its influence with time. In contrast to that, the hydraulic conductivity increases in influence on the cumulative infiltration with time and for very long infiltration durations almost becomes equal to the overall infiltration rate.

The knowledge of the infiltration rate is relevant for the transport of contaminants (including nutrients and pollutants), ground water recharge and transport of e.g. rain water to plant roots (DECAGON DEVICES, 2013). Especially the last two aspects are important for the UPAGES project, as they have influence on plant growth, and thus also on vegetative dry matter production on the pastures. Furthermore the infiltration rate can serve as a reference value to evaluate erosion risk. A further processing of the data (according to the method by ZHANG, which is described in DECAGON DEVICES, 2013, p. 15) allows also for the determination of the unsaturated soil hydraulic conductivity (KIRKHAM, 2004), a soil reference value frequently used.

The Mini Disk Infiltrometer was chosen because it works well for measurements of infiltration into dry soils (DECAGON DEVICES, 2012), a condition expected to be found in the research area during the field research period. Furthermore the Mini Disk Infiltrometer is portable and thus very suitable for infiltration measurements in the field. The advantage of this is the possibility to perform measurement on undisturbed soils (which is often not the case for infiltration measurements in the laboratory, as the used soil core samples may be compacted or disturbed through sample taking and transport). With its small devices dimensions it can be carried easily carried in a small backpack (KIRKHAM, 2004).

As drawback it was noticed, that the base of the Mini Disk Infiltrometer could get clogged when working on soils with a high content of C_{org} (KIRKHAM, 2004).

3.2.7 Methods for the determination of vegetation data

The vegetation parameters assessed were the plant species composition (qualitative and quantitative), as well as the overall vegetation coverage (in %) and the vegetative dry matter production (in g DM/m²). The assessment was performed through the application of basic methods of vegetation survey. In principle, all these methods start with the selection of a representative sample area within the vegetation unit of interest.

The area for the determination of the plant species composition was chosen according to DIERSCHKE (1994) and made up 9 m². The plant species determination was performed according to expert knowledge and specific plant identification books (e.g. VERNUß, 2010). The abundance and the dominance assessment was also performed on the same 9°m²-areal. In a first step the cover percentages for the categories moss, lichen, plants, stones, soil and litter were estimated. In a second step, based on the Braun-Blanquet

method and in accordance to DIERSCHKE (1994), the abundance and dominance of each species was determined.
For the assessment of the vegetative dry matter production representative plots of 0,5 m² and 1 m² were chosen. The vegetative biomass on these plots was cut by hand in an estimated height of 1-2 cm above the ground. During the period of the field research (15 weeks) the cut was repeated up to three times in order to simulate several possible grazing patterns. The taken samples were processed in the laboratory (see chapter 3.2.9) and the average of the sum of all respective results served as rough estimate for the annual vegetative dry matter production on the sample area. These values were extrapolated to the unit dt/ha/a.
Furthermore the root density and the effective rooting depth was measured according to the KA5 (see Ad-hoc-AG Boden, 2005). The root density was assessed through the counting of roots in a representative rooting area of 1 dm². The found roots were subdivided into fine and thick roots at a threshold of a 2 mm root diameter. The effective rooting depth is defined as the depth to which roots can grow under the given circumstances (see KA5). For the determination either digging to a root-free zone or to a root growth restricting layer was performed.

3.2.8 Application of methods in the field

The application of the methods in the field started with the selection of the sample sites in the research area. Within the framework of the UPAGES project three subareas were predefined, which differed regarding geographical location and pasture management regime (see description in chapter 3.1.1). These subareas were named: Tesyk, Tesyk summer pasture (Dschailoo) and Karatal. In each subarea one to two catenas were defined according to the principles of the "Applied Habitat Ecology". This implies the consideration of the aspects of the elevation gradient, the moisture gradient, the utilisation gradient and the relief characteristics. Along the catenas, sample sites representative for a certain topical vegetation unit were determined and mapped with the help of a GPS device (this procedure for the sample site choice was performed in cooperation with the UPAGES project working group).
After the determination of the relief position of a sample site, the determination of the vegetation parameters was initially conducted. A complete application of the above described methods (including the assessment of the vegetative dry matter production) only followed, if it was found that the concerning site represented an area of significant importance for the pasture utilisation of the analysed subarea.

In order to ensure a standardized application procedure of the different field methods, which followed the vegetation assessment, a field assessment sheet was developed. The sheet focuses on the soil assessment methods including the visual site assessment methods (see table 4). On the sheet the parameters are grouped according to the following principles: basic parameters, describing the general site characteristics are listed on the top of the sheet. The three columns below contain the indicator sets of all visual assessment methods. The indicators in the columns are grouped according to the methods they belong to by background colour of the according cells. The field assessment of the listed parameters and indicators started with the digging of a hole of about 200 mm x 200 mm wide and 300 mm deep. The excavated material was placed closely to the hole to minimize the disturbance of the sample area and to allow for an easily closing of the hole after the assessment. After the profile of the sample hole was photographed with a scale and a profile number the acquisition of the basic parameters started with the soil moisture test according to SHEPHERD (2000) (see chapter 3.2.1). To be able to determine the soil moisture also in the laboratory a soil sample was taken from the surface layer according to the description in chapter 3.2.4. The taken samples were also used to determine the bulk density. Furthermore an additional soil sample of about 100 g was taken to allow the determination of the soil texture and also of the chemical properties of the soil in the laboratory. The sampling depth varied slightly, respecting the homogeneity of the soil layers, but was never deeper than 150 mm.

The assessment of the resistance to penetration of the soil was conducted a minimum of four times at each sample site. The resistance-to-penetration values were measured and recorded in intervals of 2 cm to a maximum depth of 0,5 m. The sample spots were chosen close by each side of the quadratic hole. After adjusting the cone diameter to the expected soil resistance, the cone was pushed into the ground with a steady rate of 2 cm/sec. During the whole field assessment, cones with base areas of 1 and 2 cm² with a corresponding diameter size of 11,28 mm and 15,96 mm were used. In cases, when stones apparently and strongly disturbed the measurement, the instance was noted down. At various sample sites a high content of coarse material of the soil did not allow to perform the measurement to the norm depth at all, also when the applied forces exceeded 800 N (maximum threshold value for safe measuring devise use) using the smallest cone size. In these cases the four deepest attempts were considered in the interpretation of the results. Maximum Penetration Resistance (MPR) and depth to MPR to a depth of 200 mm, as measure for the structural soil condition within the topsoil were as well noted down to take especially livestock induced compaction into account (see chapter 2.2).

For the in situ measurement of the infiltration a vegetation-free, representative soil spot was chosen in the close surrounding of the sample sites. The infiltration was conducted at a pressure head of approx. -2 cm (as recommended in the Decagon User's manual) and an infiltration volume of 15-20 ml was aimed at to allow an accurate calculation of the hydraulic conductivity (DECAGON DEVICES, 2012). As the rainfall acceptance rate was of primary interest it was taken care to avoid damaging the crust before and during the measurement process. After the termination of these measuring procedures the application of three visual field methods followed.

For each indicator of the VSA method, of the MSQR method and of the method according to Etzold two separate values were noted down. On the one hand this was the actual site condition in terms for threshold values and on the other hand the corresponding rating value of the different visual methods were as well noted down to take especially livestock induced compaction into account (see chapter 2.2).

During the whole research period, the assessment of the selected sample sites was repeated twice. The first assessment took place in the beginning of June 2013 and the second assessment was conducted in the middle of July 2013 (see table 3).

Table 3: Overview of the working schedule of the field research in Kyrgyzstan in the summer 2013

Date	Working zone	Plot-no.	Comments
First assessment period			
20.05.2013 - 31.05.2013	Biskek	preparation of the field assessment trip	
01.06.2013 - 07.06.2013	Tesyk	A13101 - A13219	additional construction of enclosure of reference plot
08.06.2013 - 09.06.2013	Karatal	B13300 - A13406	reassessment of the plots of the research period 2012
10.06.2013 - 12.06.2013	Tesyk summer pasture	C13501 - C13510	some life stock already on the summer pasture
Second assessment period			
01.07.2013 - 08.06.2013	Biskek	preparation of the field assessment trip	
09.07.2013 - 11.07.2013	Tesyk summer pasture	C13501 - C13510	bad weather conditions (snow)/ all life stock on summer pasture
12.07.2013 - 16.07.2013	Tesyk	A13101 - A13219	very little to no life stock
17.07.2013 - 18.07.2013	Karatal	B13300 - A13406	lifestock number did not change

3.2.9 Laboratory work

For the soil samples the analysis started with the determination of the BD. The weighted samples, taken with the Soil Core Sampler were oven dried at 105 °C until mass consistency was achieved. As the volumes of the samples were known, the BD could be calculated by dividing the measured weight by the given volume (also see DIN ISO 11272). To determine the soil moisture content a 10 g sample was also oven dried at 105 °C until the achievement of mass consistency and was then again weighted. Through the calculation of the "weight difference" the moisture content could be determined. This analysis was conducted following the definitions given in the DIN ISO 11465. The soil texture composition for the fraction < 2 mm was conducted through a combination of sieving and sedimentation. For the fraction > 0,063 mm sieving was applied, while all smaller material was classified using the so called "KÖHN pipette". In the DIN 19683-1 this analysing process is defined. Besides physical soil parameters also chemical parameters were assessed in the laboratory. For the determination of the pH-value a soil water suspension had to be prepared (10 g soil and 25 ml of 0,1 mol $CaCl_2$-solution). The VDLUFA A 5.1.1 norm defines the frame for this measurement. On the basis of the released amount of CO_2, which is caused by the reaction of carbonates and hydrochloric acid and which is measured by the Scheibler-apparatus according to DIN ISO 10693, the overall carbon content of the soil sample could be determined. In order to assess the amount of organic carbon (C_{org}) additionally an analysis according to DIN ISO 10694 had to be performed. This analysis was performed with the help of the "vario MAX CNS / CN" elemental analyser.

The analysis of the content of the macro element nitrogen (N) was also conducted using the "vario MAX CNS / CN" elemental analyser, but according to the principles of the DIN ISO 13878.

To obtain the dry matter weight of the vegetative biomass samples, the cut probes were put in a drying cabinet. During the following drying process the temperature never exceeded 55 °C. The samples stayed in the cabinet until mass consistency was reached and were then weighted. The resulting values represented the DM values of the samples.

3.2.10 Analysis and interpretation of the collected data

The data collected during the field work in the summer period of 2013 was analysed and interpreted in several ways. First of all the data set obtained through the application of VSA field method was interpreted with the method specific evaluation system. During this process each indicator was evaluated on whether it was well applicable in the field or not. In particular, the special field conditions of the research area, like mountainous relief and steep slopes, were regarded. Furthermore the results of the first and second assessment were compared with each other. A special focus was also set on the comparison of the results obtained in the different pasture management units (winter/"all-year"-pasture and summer pasture/Dschailoo).

In a second step the two additional field methods of visual site assessment also analysed regarding their applicability and their final results.

A third way of analysis and interpretation of the collected data was realised through the comparison of the site evaluation values against the data obtained through the application of the standard field measurements and of the laboratory-based analyses. The VSA final site ratings as well as different indicator scores were regarded in this inquiry.

The software used during the process was the statistical package SPSS (IBM SPSS Statistics, version 22, 2013). For the statistical analysis descriptive analysis was performed by tabulating means (and their standard deviations) using all available data. Due to occasional missing data, relationships between the visual assessment scores and the other measured soil properties were examined using those subsets of data that were pairwise present. For the validation of the soil physical and chemical data the calculation of correlation coefficients was performed. The correlation coefficients Spearman's rank correlation coefficient ρ (Spearman's rho) had to be chosen, because the data was not normally distributed and metrical scaled. For the comparison of the results of the visual site evaluations and the soil and vegetation data the Kendall rank correlation coefficient τ (Kendall's tau) was calculated as ρ is sensitive for tied values (rank equalities).

The results of both calculated correlation coefficients ρ and τ rank between -1 and +1. In this scale, 0 means no correlation, while -1 means a perfect negative correlation and +1 a perfect positive correlation. Because there are no standard values for the interpretation of non-perfect values, the following categories for describing Spearman's rho and Kendall's tau are proposed (according to BECKER, 2012):

- to 0.25: no correlation,
- 0.26 to 0.50: weak correlation,
- 0.51 to 0.75: moderate correlation,
- 0.76 to 1.00: strong correlation.

In the following chapter the results of the described analyses and interpretations of the collected data are presented.

3.2.11 Annexes

All original data of the field assessment was digitalized into the format of excel sheets. These excel sheets, as well as all visualisations of the data assessed are saved on the added CD, which can be found in the back cover of the thesis.
Furthermore on the CD data can be found, which includes pictures of the research area, maps and further reading material. The contained "Read me"-file gives detailed explanations on how the data on the CD is structured and which information can be found where. The data formats comprise: .doc-, tif-, .jpg-, .pdf- and .xls-files.
In the text of this thesis cross-references to these files will be made.

Table 4: Field work sheet

Profile nr.	North coordinate	East coordinate	AMSL	Date	
Slope [°] [%]	Exposition	Relief position	Weather conditions	Sample no.	
Penetration resistance	Soil moisture content	Infiltration rate	Bulk density	Corg content	
Soil texture/substrate		Pasture quality (Brix value)		Contamination	
Soil structure		Clover nodules		Salinisation	
Soil porosity		Weeds		Sodification	
Number and colour of soil mottles		Pasture growth		Acidification	
Soil colour		Pasture colour and growth relative to urine patches		Low total nutrient status	
Earthworm number		Pasture utilisation		Soil depth above hard rock	
Soil smell		Root length and root density		Drought	
Potential rooting depth		Area of bare ground		Flooding and extreme waterlogging	
Surface ponding		Drought stress		Steep slope	
Surface relief		Production costs to maintain stock-carrying capacity		Rock at surface	
Bedrock		Browsing tracks [%]		High percentage of coarse soil texture fragments	
Depth of A horizon or depth of humic soil		Plant diversity, [%] flowering plants., No. of species on 3x3 m		Unsuitable soil thermal regime	
Subsoil compaction		Rubble/scree on surface		Miscellaneaous hazards	
Profile available water		Cattle tracks [%] on 10x10 m		Erosionstracks [%] on 10x10 m	
Background colour indicates the method to which the parameters belong to (some indicators belong to two different methods)		VSA indicators	MSQR indicators	"Etzold" indicators	

4 Results

The results presented are the outcomes of the field assessment at 53 sample sites during the first research period and of 51 sample site assessments during the second period. The difference between the first and the second period in the sample site number assessed, was due to unfavourable weather condition during the second assessment period and a very limited timeframe for the assessment work in the field in general. The number of soil samples taken summed up to 104. The obtained results can be divided into three parts: The first part consists of the results of the VSA method application. In the following besides the final numerical results and the overall site evaluations according to the VSA method, additional information will also be presented on the applicability of the single indicators in the field under the specific conditions on site. In this context the term "applicability" refers to the aspect of "How well could the different indicators be applied". The presented evaluations are equally valid for the first and the second assessment period, as well as for all three management units, as the related site variations did not lead to major changes in the overall applicability.
The second and the third part consist of the results of the two additionally applied visual field assessment methods and the results of the standard field measurements. The calculated correlations to the VSA indicator values are also presented in this context.

4.1 Visual Soil Assessment method

The final results of the VSA method are summarized in table 5 (this table, as well as additional information on the topic, can also be found in the file "Results of the VSA method complete" on the CD).
The scores of the SQI ranged between 16 and 40,5 for the first assessment period and between 17,5 and 38 for the second assessment period. On average the score of the single sites varied 4 points (min. 0 points and max. 10 points) between the two periods, which is equal to an 15 % average change. The scores for the PPI ranged between 11,5 and 30,5 for the first assessment period and between 12 and 29 for the second assessment period. On average the score of the single sites varied 3 points (min. 0 points and max. 6 points), which is equal to an 10 % average change between the two assessment periods.

Table 5: Results of the VSA method

	1. assessment period				2. assessment period			
Sample site	SQI	SQA	PPI	PQA	SQI	SQA	PPI	PQA
A13 101	26,5	moderate	19	poor	24,5	moderate	17,5	poor
A13 102	33	moderate	28	moderate	34	moderate	25	moderate
A13 103	32	moderate	22,5	moderate	28,5	moderate	23	moderate
A13 104	34,5	moderate	22	moderate	28,5	moderate	17,5	poor
A13 105	34	moderate	23	moderate				
A13 106	33,5	moderate	20	moderate	28	moderate	20,5	moderate
A13 107								
A13 108	28,5	moderate	22	moderate	27	moderate	19,5	poor
A13 109	20,5	moderate	19	poor	25,5	moderate	16,5	poor
A13 110								
A13 111	22	moderate	10	poor	26,5	moderate	11	poor
A13 112	17	poor	6	poor	20	moderate	7,5	poor
A13 113	14	poor	7,5	poor	14	poor	7,5	poor
A13 201	31,5	moderate	26	moderate	27,5	moderate	24,5	moderate
A13 202	26,5	moderate	19	poor	20,5	moderate	25	moderate
A13 203	29	moderate	27,5	moderate	37	good	27,5	moderate
A13 204	29	moderate	29	moderate	34	moderate	26	moderate
A13 205	30,5	moderate	17,5	poor	28	moderate	20,5	moderate
A13 206	23	moderate	12	poor	18	poor	16	poor
A13 207	17,5	poor	14	poor	13	poor	11	poor
A13 208	26	moderate	13	poor	32,5	moderate	14	poor
A13 209								
A13 210	14,5	poor	20	moderate	17,5	poor	23	moderate
A13 211	8	poor	17	poor	10	poor	13,5	poor
A13 212	13	poor	18	poor	12	poor	14,5	poor
A13 213	40	good	21	moderate	30	moderate	21	moderate
A13 214								
A13 215	31,5	moderate	21	moderate	33	moderate	20,5	moderate
A13 216	36	good	25	moderate	31,5	moderate	29	moderate
A13 217	35,5	good	20	moderate	35,5	good	21,5	moderate
A13 218	32,5	moderate	28	moderate	34	moderate	26	moderate
A13 219	35,5	good	21	moderate	29	moderate	20,5	moderate
B13 300	31	moderate	23	moderate	32,5	moderate	19	poor
B13 301	25,5	moderate	19	poor	30	moderate	19	poor
B13 302	32	moderate	18,5	poor	33	moderate	20,5	moderate
B13 303	16	poor	20,5	moderate	18,5	poor	20,5	moderate
B13 304	18,5	poor	20	moderate	18,5	poor	18	poor
B13 305	18	poor	19	poor				
B13 306	18	poor	19	poor	17,5	poor	17	poor
B13 307	18	poor	20	moderate	18,5	poor	17	poor
B13 308	18	poor	17	poor	23,5	moderate	17	poor
B13 401	25	moderate	14,5	poor	29,5	moderate	18	poor
B13 402	29	moderate	20	moderate	35,5	good	21	moderate
B13 403	33,5	moderate	21	moderate	38	good	19	poor
B13 404	27,5	moderate	23,5	moderate	36	good	21,5	moderate
B13 405	30,5	moderate	22,5	moderate	34,5	moderate	20	moderate
B13 406	32	moderate	19	poor	25	moderate	14,5	poor
C13 501	30	moderate	20	moderate	33,5	moderate	20,5	moderate
C13 502	34	moderate	27,5	moderate	37	good	26	moderate
C13 503	40	good	30,5	moderate	35,5	good	26	moderate
C13 504	40,5	good	30	moderate	36	good	25,5	moderate
C13 505	38,5	good	27	moderate	33	moderate	27	moderate
C13 506	31,5	moderate	24	moderate	33	moderate	22,5	moderate
C13 507	25,5	moderate	22,5	moderate	32,5	moderate	17,5	poor
C13 508	28	moderate	23	moderate	30,5	moderate	21	moderate
C13 509	30,5	moderate	23	moderate	31,5	moderate	24,5	moderate
C13 510	21	moderate	11,5	poor	18	poor	12	poor

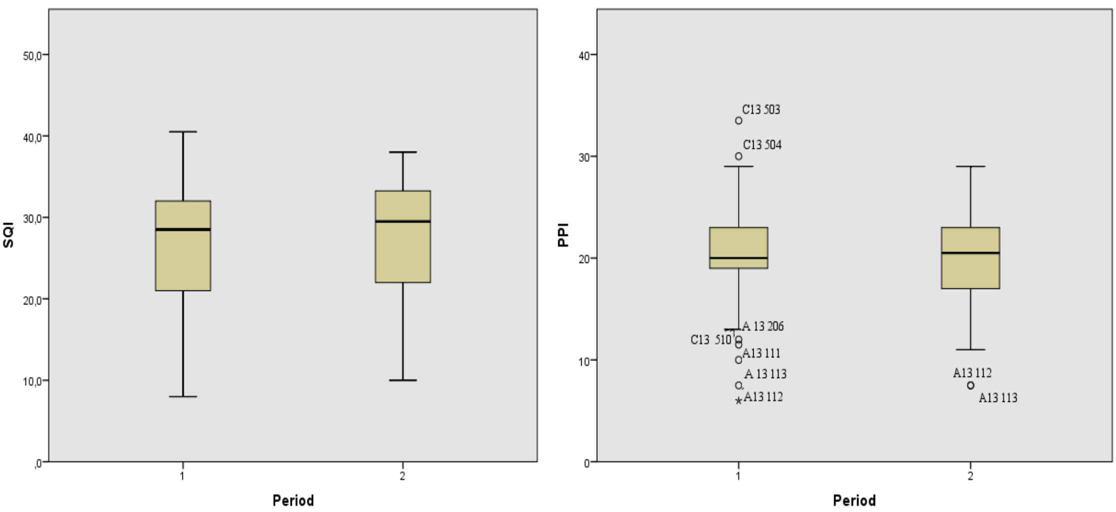

Figure 7: Boxplots of the SQI and PPI results, respectively for the first and second assessment period

Derived from the data given above and by looking at the boxplots shown in figure 7 it can be stated that the final results of the SQI and the PPI are very similar for both assessment periods. This is consequently also true for the derived SQA and the PQA results (see table 5).

In the SQA – PQA contingency table (see table 6) it can be seen that in more than half of all cases the soil and the plant assessment results are equal (equality is indicated through a yellow colour of the respecting cells) and that in more than one third of all cases the SQA score is one unit higher than the corresponding PQA score.

Table 6: SQA – PQA contingency tables of the first and the second assessment period

1. assessment period		PQA poor	PQA moderate	PQA good	plot no. sum
SQA	poor	9	4	0	13
SQA	moderate	11	22	0	33
SQA	good	0	7	0	7
plot no. sum		20	33	0	53

2. assessment period		PQA poor	PQA moderate	PQA good	plot no. sum
SQA	poor	9	2	0	11
SQA	moderate	13	19	0	32
SQA	good	1	7	0	8
plot no. sum		23	28	0	51

By subdividing the results with regards to the different management units summer pasture and winter/all-year pasture another characteristic could be made out: The plots on the summer pasture obtained on average a SQI score of 32 points and a PPI score of 23, while the plots on the winter/all-year pasture scored on average lower (with an average SQI of 26,5 and an average PPI of 19). This characteristic was found true for the results of the first assessment period, as well as for the results of the second assessment period (see figure 8).

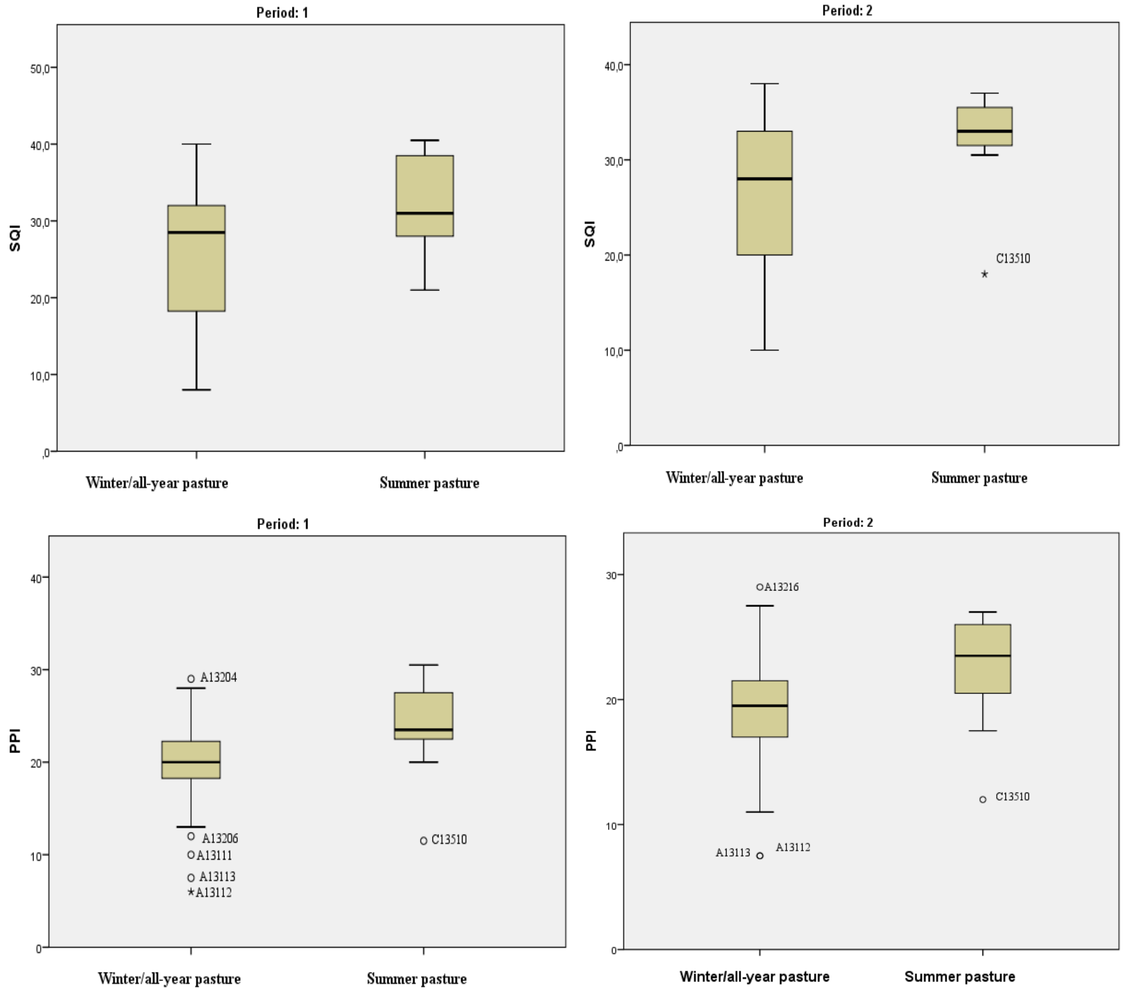

Figure 8: Boxplots of the SQI values and PPI values respectively for the winter/all-year pasture and the summer pasture, subdivided by period

4.1.1 Soil Indicators

The soil indicator "soil texture" was assessed in the field using the "finger method" described in the VSA field guide. It was found particularly not easy to distinguish with certainty between the closely related textural classes "sandy loam" and "loamy sand".

The assessment of the soil indicator "soil structure" was often complicated by the relief (steep slopes) in the research area leading to technical problems. The, for the performance of the drop-shatter test, needed plastic basin could often only be placed with difficulties. Furthermore, it was found and approved (according to SHEPHERD et al., 2000, p. 4) that the drop-shatter test does absolutely not work at sites with a high soil moisture level. These conditions occurred rarely and in particular only at sample sites in the topographical position "valley bottom". For references, see pictures 1 and 2 in figure 9.

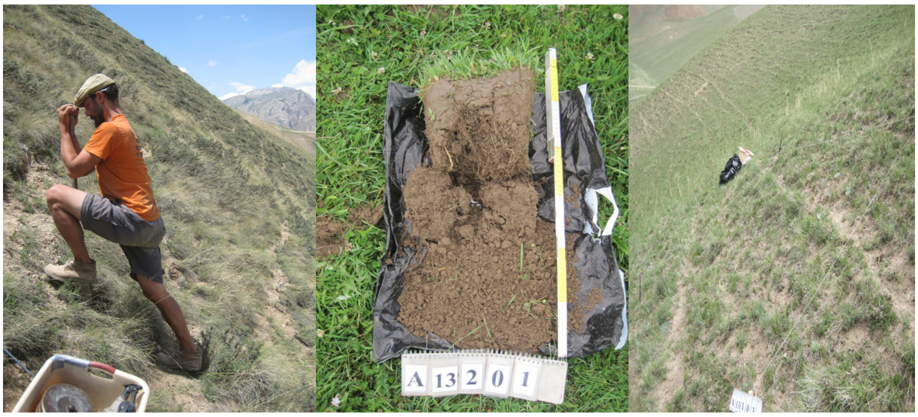

Figure 9: Sample site B13403, 2. Result of drop-shatter test, 3. Surface relief; pictures taken in the course of the first assessment period

The visual scoring of the indicators "soil porosity" and "number and colour of soil mottles" could be performed without complications. The reference descriptions and pictures in the field guide correlated well with the field conditions in the research area.
In the VSA manual a reference soil "from under a close by fence" (a site protected from utilisation) is used for the rating of the indicator "soil colour". Such a reference soil could not be made out in the research area, as fences are generally not used and other protect areas also only rarely occur. The soil colour was therefore not determinable under the field conditions and was instead determined with the help of the Munsell colour system.
The reference descriptions of the indicator "earthworms" were, besides the classification scale (see chapter 5.2.2), well correlated with the found field conditions and the earthworm count could be easily performed.
The performance of the indicator assessment "soil smell" was perceived as tricky. The scoring depended on a judgment, which had to be made without having a "real" reference value. The descriptions of the soil smells given in the field guide indicate how to distinguish between different kinds of smells, but this did not fully substitute for a reference "smell value".
The indicator "potential rooting depth" could be assessed well with the given instructions. However the assessment required often a lot of effort. A high amount of coarse material made it sometimes impossible to reach the full depth of the rooting

zone. In these cases the actual rooting depth was rated according to own estimations and experiences.

The visual scoring of the indicator "surface ponding" was not possible in the way the field guide proposes. This was because during both assessment periods no wet periods occurred. The scoring was therefore performed taking the relief and the local climate conditions into account. Informative talks with local land users also helped to obtain the information needed.

For the assessment of the indicator "surface relief" the description of the respective conditions were used approximately, as these and the pictures in the guide did not reflect the surface relief types present in the research area accurately. As shown in picture 3 in figure 9 the relief was mostly disturbed by cattle tracks rather than by unregular treading.

4.1.2 Plant Indicators

The first plant indicator, the "pasture quality", was scored on the basis of the assessment of the green leaf herbage and legume cover. This reference value could be applied well. In contrast to that further indications given to assess the indicator, such as the brix sugar value, indicator species and pasture composition relative to the originally sown seed mix, could not be used. One reason was that the described evaluation process for the brix sugar value did not work in the field. This was mainly due to the fact that through the methods recommended no usable plant juice sample could be obtained. Picture 1 in figure 10 shows an unsuccessful attempt to obtain a plant juice sample, which finally even led to the damage of the used garlic crusher.

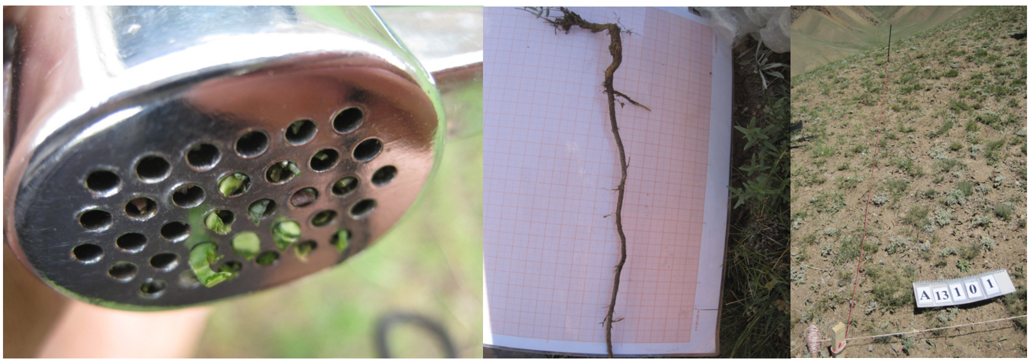

Figure 10: 1. Attempt to obtain a plant juice sample; typical legume 2. Root growth pattern, 3. Sample picture of the indicator assessment "area of bare ground; pictures taken in the course of the first assessment period

Regarding the indicator species: only one of the listed species (white clover, *Trifolium repens*) could be identified in the vegetation present on site.

The indicator "clover nodules" could not be assessed under the given field conditions. This was because clover occurred only very rarely in the species composition. Therefore it was decided to refer to other legume species, when clover plants were absent. The second picture in figure 10 shows a typical root growth pattern of legumes in the research area (shown here: *Astraglus spec.*). The tendency of legume species to develop a taproot was observed many times in the research area. Nodules could only very rarely be found on this type of root system. An indicator assessment as outlined in the field guide was therefore not possible.

In contrast to that, the visual scoring of the indicator "weeds" could be well performed with the reference pictures given, but with regards to the listed indicator species difficulties occurred: only two of the species (thistle, *Carduus* and buttercup, *ranunculus*) could be identified in the present vegetation composition.

For the indicator "pasture growth" the determination of the dry matter production was realised through herbage cut. Concerning the practicability of this determination procedure, the needed effort and the dependency on good infrastructure was regarded as high. As for the other methods described in the field guide to assess this indicator, also a lot of effort, good theoretical knowledge and/or experience of visual vegetative dry matter approximation seemed to be needed.

The indicator "pasture colour and growth relative to urine patches" could be well assessed with the description and the reference pictures given.

In contrast to that the "pasture utilisation" could not be assessed according to the field guide. In the guide it is stated that the scoring should be performed "at or near the end of the grazing period" (SHEPHERD, et al. 2000). Especially for the research area "Tesyk summer pasture" the opposite time, in other words the beginning of the grazing period, was the moment of the actual assessment. As the field research time was limited, there was no alternative to this working schedule. Nevertheless, regarding the applicability of the indicator it was found that the pictures in the field guide were clearly reflecting possible pasture conditions in the research area.

Just like the indicator "pasture utilisation" the indicators "root length and root density" and "area of bare ground" could also not be assessed according to the description given. This was also due to differences between the assessment timing recommended in the guide and the actual time of the year when the scoring was performed (e.g. while the actual assessment time was the beginning of the summer and the summer, the assessment of the indicator "area of bare ground" is foreseen for the winter/early spring period, while the assessment of the "root length and root density" is foreseen for late autumn/early winter). Nevertheless, the further indications regarding the two indicators "root length and root density" and "area of bare ground" could be applied well in the field. This is especially due to the high conformity of the reference pictures with the actual appearance of the respecting conditions at the sites (compare the respecting field guide pictures (p. 63) with picture 3 in figure 10).

The scoring of the indicator "drought stress" could not be performed according to the assessment description in the field guide. The required knowledge of the immediate paddock history could not be obtained. This meant that the processes of "browning-off" and "recover after rainfall" of the pasture could not be evaluated as the necessary processes did not occur during the assessment period. Furthermore, the listed indicators species could not be identified in the natural given plant composition in the research area.

Due to the pasture management system in use, the last listed indicator "production costs to maintain stock-carrying capacity" could not be scored at all. In the research area the pastures are not personal property of the users and additional production costs do not occur since no melioration processes are carried out.

4.2 Müncheberg Soil Quality Rating

The results of the MSQR method are summarised in table 16 (see chapter "Annexes") and can also be found in the file "Results of the MSQR method" on the CD. Due to technical problems the plot A13105 could not be assessed during the first period. This is why the overall site number assessed with the MSQR method, was reduced to 103. The remaining scores of the basic soil score ranged between 13,5 and 29 for the first assessment period and between 13 and 29 for the second assessment period. On average the scores of the single sites varied 1 point (min. 0 points and max. 4 points), which is equal to an 4,7 % average change. The scores for the SQR ranged between 2,7 and 14,5 for the first assessment period and between 2,6 and 14,5 for the second assessment period. On average the SQR scores of the single sites varied 0,5 points (min. 0 points and max. 2 points), which is also equal to an 4,7 % average change (see boxplots shown in figure 11).

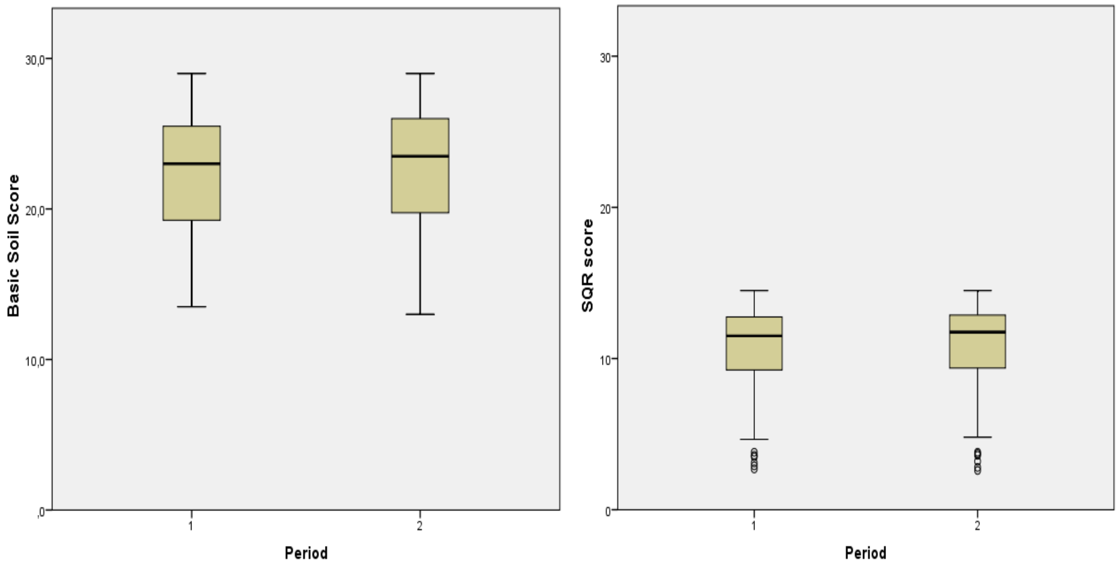

Figure 11: Boxplots of the basic soil score and SQR score for the first and second assessment period

The derived basic soil assessment and SQR assessment results are summarised in table 7. It can be seen that the results of the basic soil assessment range between "poor" and "good" and hence cover all possible assessment levels. For the first and the second period, the overall outcomes are almost equal. With regards to the SQR assessment, it can been stated that all assessment outcomes fell into the category "very poor" (see table below). Ratings in the remaining four assessment categories did not occur.

Table 7: Basic soil assessment and SQR assessment results for first and second assessment period

Basic Soil Assessment	1. assessment period	2. assessment period
poor	15	13
moderate	33	35
good	4	3
plot no. sum	52	51

SQA	1. assessment period	2. assessment period
very poor	52	51
poor	0	0
moderate	0	0
good	0	0
very good	0	0
plot no. sum	52	51

With regards to the different management units no significant difference in the basic and the final soil assessment results could be made out. Even though the scores for the summer pasture unit were slightly higher than the scores of the winter/all-year pasture units (indicated in the boxplots shown in figure 12), this change did not lead to a difference in the overall assessment outcomes.

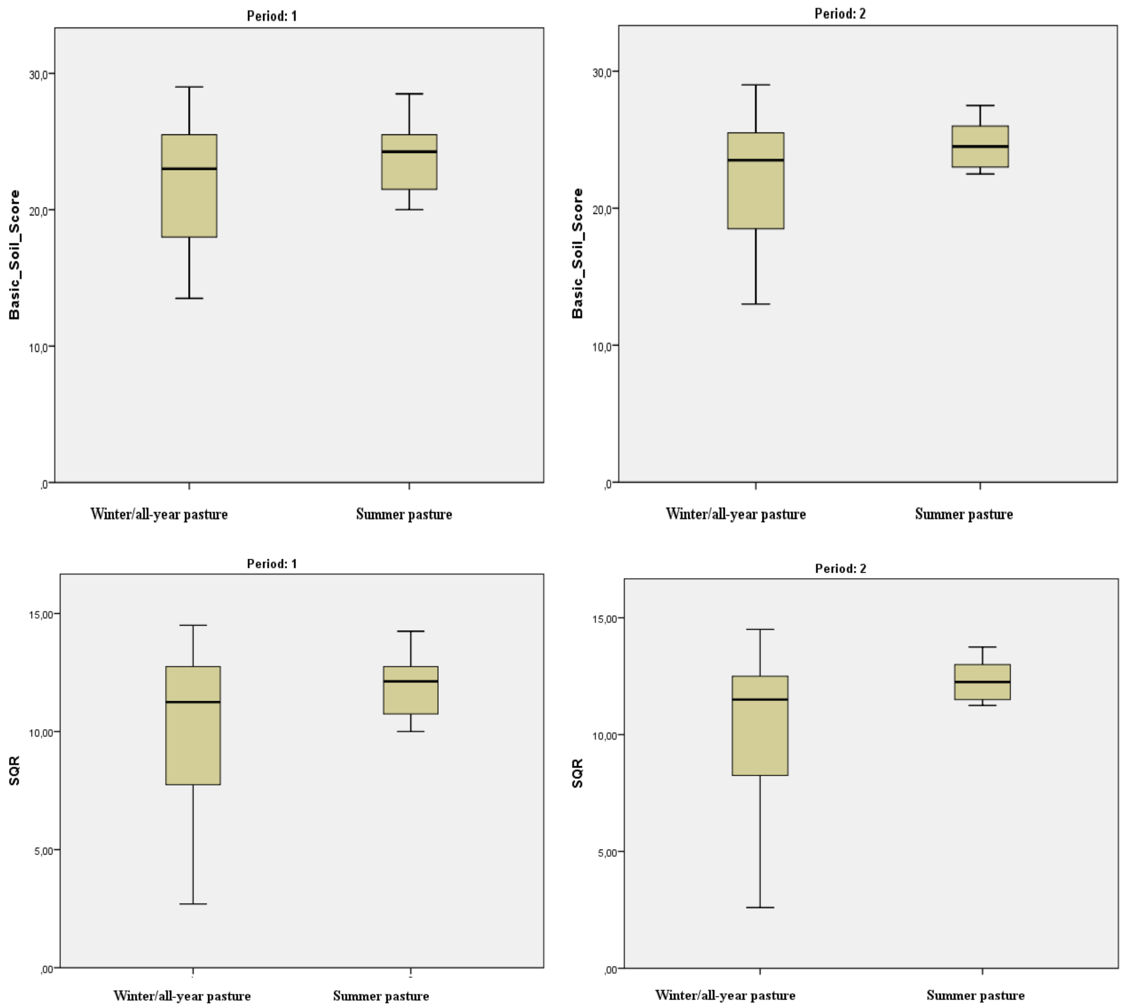

Figure 12: Boxplots of the basic soil scores and SQR scores, respectively for the winter/all-year pasture units and the summer pasture unit, subdivided by period

4.2.1 Basic soil indicators

The evaluation method of the basic soil score indicator "substrate" is identical with the evaluation method of the VSA soil indicator "soil texture". Therefore the assessment in the field was performed uniformly (see chapter 4.1.1).

The evaluation of the soil indicator "depth of the A horizon/ humic soil (d_h)" turned out to be rather difficult in the field. In the MSQR guide a threshold of a soil organic matter (SOM) content of 4 % is given as characteristic for a humic soil. At the majority of the sites it was not possible to make out the SOM threshold value with certainty. Additionally the guide proposes, in cases of a SOM content lower than 4 %, to use the depth of the rooting zone as substitution value. As in some cases also the depth of the rooting zone could not be determined with certainty (cf. applicability of the indicator "rooting depth and depth of biological activity") the scoring of indicator "depth of the A horizon/ humic soil (d_h)" seems not to be highly representative for the actual soil conditions found.

Just like the indicator "soil texture", the MSQR indicator "topsoil structure" is identical with regards to the evaluation procedure to an indicator of the VSA method. Therefore the assessment method, in this case the "drop-shatter-test", could be used for both methods uniformly (see chapter 4.1.1).

A further conformity of the MSQR method with the VSA method is expressed through the utilisation of the "number and colour of soil mottles" as indicator for "subsoil compaction". Regarding the description and scales for the evaluation of this indicator the MSQR orientation guide corresponds fully with the VSA field guide. As stated above (see chapter 4.1.1) the assessment could be well performed.

The assessment of the indicator "rooting depth and depth of biological activity" required often a high amount of effort. A large amount of coarse material made it sometimes impossible to reach the full depth of the rooting zone. In these cases the potential rooting depth was estimated according to own estimations and experiences.

The assessment of the indicator "profile available water" was as well only possible under difficulties. One of the references given to evaluate the indicator is valid for "temperate humid conditions" and "assumes the soil profile [to be] saturated to field capacity at the beginning of the vegetation period" (MUELLER, et al. 2007, p. 23). Due to the dominate cold semi-arid macro climate, this reference could not applied in the research area. Therefore "Grassland Wasserstufe" concept of the KA5, was used, which is also listed in the guide (for details see the file "Grasslandwasserstufe"-concept on the CD).

The evaluation of the indicator "wetness and ponding" according to the MSQR guide was rather difficult to perform. Again the given references were rather focused on areas in humid to sub-humid climate zones or on areas within Europe (e.g. reference to "mean wetness number of vegetation" acc. to ELLENBERG et al., 2001). As no wet period occurred during the research period also the described " " could not be verified on site. Consequently the indicator "wetness and ponding" was scored taking other factors into account. These were foremost the "relief position" in combination with the measured soil moisture content.

The indicator "slope and relief" could be well performed as the reference descriptions in the MSQR manual correlated well with the field conditions found.

4.2.2 Soil hazard indicators

The evaluation of the hazard properties of the research site through the scoring of the hazard indicators was only partly possible in the field. The main reason was that the requirement of field measurements with measurement equipment in order to obtain a reliable assessment basis was not met. In MUELLER et al. (2012) it is stated that, "if common indicators like vegetation are not enough sensitive to score "acidification", "sodification" or "salinisation", a field test kit for measuring pH and the electric conductivity may be very helpful". As the indication through the vegetation were not sensitive enough/could not be interpreted unambiguously and the required measuring equipment was not available, the scoring of the above named indicators and also of the indicators "contamination" and "low total nutrient status" could not be performed. Furthermore the indicators "drought" and "unsuitable soil thermal regime" could not be scored with certainty on the basis of observations in the field. Even though a temperature measurement was performed in the course of the field work, additional information to calculate e.g. the "Aridity Index according to De Martonne" needed to be obtained from the Naryn weather station (like e.g. annual temperature and precipitation distribution). The weather station is located about 50 km south-east of the research area and the information was only available 5 month after the field research period.

As for the remaining six hazard indicators an assessment in the field was conducted according to the descriptions. The scoring tables of these indicators ("soil depth above hard rock", "flooding and extreme waterlogging", "steep slope", "rock at the surface", "high percentage of coarse soil texture fragments" and "miscellaneous hazards") contained helpful indications and classifications which could be well used in the field. The evaluation of some indicators (e.g. "flooding and extreme waterlogging) was performed not only based on own observations, but also took information obtained through informative talks with local land users into account.

4.3 Method according to Etzold

The final results of the field evaluation according to the method of Etzold are represented in the scores of the "Susceptibility to Erosion-Index" (SEI) and of the "Pastrue Degradation Index" (PDI) (see table 17 in the chapter "Annexes" and the file "Results of Method acc Etzold" on the CD). Just like for the MSQR assessment the plot A13105 could not be assessed during the first period. This is why the overall site number, sampled with the method acc. Etzold, was also reduced to 103. The rating of the overall site conditions ranged from "low" to "medium" regarding the potential erosion on the sites (SEI), and from "low" to "strong" with respect to the current state of degradation (PDI) on the pasture sites.

The scores of the SEI ranged between 38,3 and 80,6 for both assessment periods. There was no change of any single indicator score between the two periods. The scores of the PDI ranged between 25 and 80 for the first assessment period and between 25 and 79,4 for the second assessment period. On average the scores of the single sites varied 3,6 points (min. 0 points and max. 12,5 points), which is equal to an 7,2 % average change. The boxplot (see figure 13) illustrates that the final PDI scores were similar for the two different assessment periods.

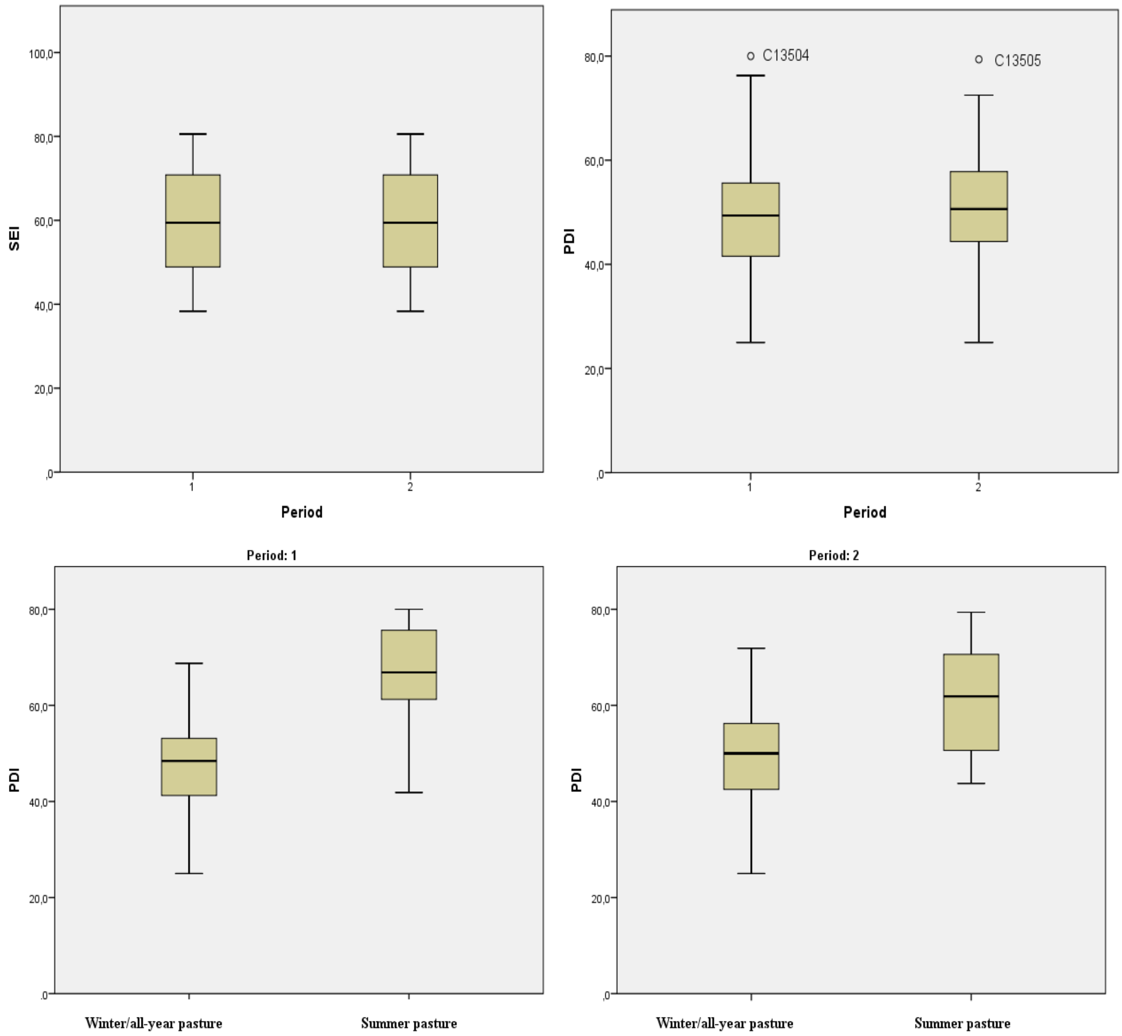

Figure 13: Boxplots of the PDI results of the winter/all-year pasture units and the summer pasture units, subdivided by period

The corresponding site assessments, expressed in denotations are summarised in table 8. The susceptibility to erosion was rated as "medium" in 65 % of all cases and as "low" in the remaining 35 % of the cases. The assessment of the PDI also resulted in the rating "medium" for the majority of the cases (82 %). The remaining sites were assessed as "low" (8 % of all cases) and "high" (10 % of all cases).

Table 8: SEI assessment and PDI assessment results of the first and second assessment period

Susceptibility to Erosion-Index	1. assessment period	2. assessment period	plot no. sum
Low risk	18	18	36
Medium risk	34	33	67
High risk	0	0	0
plot no. sum	52	51	103

Pasture Degradation Index	1. assessment period	2. assessment period	plot no. sum
Low	5	4	9
Medium	41	43	84
Strong	6	4	10
plot no. sum	52	51	103

With regards to the different management units a difference in the results could only be made out concerning the PDI scores: An average a PDI score of 62 was calculated for the summer pasture unit, while the average PDI score for the winter/all-year pasture units was lower by 26 %, reaching only 46 (see figure 13).

4.3.1 SEI Indicators

The indicator scores of the SEI are based on the assessement of the physical site conditions, which are independent from the impact of the site utilisation. These indicators are the "inclination" (regarded twice in the index calculation), the "altitude", the "aspect", the "topographic position", the "slope" and the "bedrock". With the recommended equipment all of these indicators, except for the indicator bedrock, could be easily assessed. As for the classification of the bedrock material: The description in the field guide are designed for the assessment of the naturally present bedrock types in the Shahdag region (Azerbaijan). Therefore the given indications are rather specific, covering only the classes "Limestone", "Other (solid)", "Mix", "Slate", "Other (soft)". In contrast to that the obtained information on the bedrock material in the research area was rather general. Detailed information from geological maps could not be obtained and a bedrock classification in the field was not possible due to high amounts of coarse material in the upper soil layers. With reference to the measured pH values in the upper soil layer, which indicated the presence of carbonates, it was decided to classify the bedrock material in the research area as "mixed". This decision was also based on the perception that the carbonate –material was in the form of "rubble".

4.3.2 PDI Indicators

The indicators "bare soil", "rubble and scree", "rocks", "cattle tracks", "erosion tracks" and "browsing" are all supposed to be assessed as cover percentage value of an 10 m^2 area. Due to the topography (characterised by extremely step slopes) the assessment area was reduced to 9 m^2. The results were extrapolated to a 10 m^2-reference value in the aftermath of the field work. In the field the distinction between the indicators "rubble and scree" and "rocks" was found to be rather difficult, as no threshold value to distinguish between these two categories (e.g. an object diameter) was given. The application of all other listed indicators was quickly and easily possible.

In contrast to that the assessment of the indicators "number of plant species" and "cover grazing indicator species groups" was very time consuming and only possible with the help of T. Heinicke (an UPAGES team member). The plant species composition and the abundance and dominance of each species were determined according to DIERSCHKE (1994) using e.g. the Braun-Blanquet method, as no other specific evaluation method was proposed in the field guide. Therefore the scoring of the respecting visual indicator and the outcomes of the scientific research methods correspond fully.

The indicator "flowering" could not be assessed with certainty in the field. The indicator scoring values in the field guide "few", "medium" and "a lot" are given without any further reference values, which made an exact scoring impossible.

4.4 Results of the soil and vegetation data measurements

In this subchapter the results of the standard field measurements and the laboratory-based analyses of the soil and the vegetation data are presented. An overview of the obtained results can be gained by looking at the files "Soil analyses results", "Vegetation analyses results" and at the folders "Soil Resistance to penetration" and "Infiltration" on the CD.

4.4.1 Soil texture

Due to the limited capacities of the laboratory and the soil texture analysis being a very time consuming procedure, the soil samples taken during the second period could not be analysed within the frame of the thesis at hand. Furthermore one sample (sample number B13302) was reported as "missing". As the resulting amount of analysed reference values was therefore considered to be too small to permit a detailed statistical evaluation, the results of the soil texture analysis are presented in rather general terms.

Looking at the results of the soil texture analysis it can be stated that the topsoil texture in the research area is mainly characterised by a high content of silt: in 58 % of the 50 analysed samples the silt content of the fraction < 2 mm was well over 50 %, and in 75 % of the samples the silt content was not less than 40 %. Extremely high values were measured in the subarea "Tesyk summer pasture", where 70 % of the 10 samples contained more than 50 % silt and the plot where the maximum silt content of 83 % was measured also occurred in this subarea (sample site C13502).
In figure 14 it can be seen, that the most frequent textural class according to SHEPHERD (2000) was "loamy silt", which occurred at 69 % of the 52 sample sites. This textural class combines the texture classes Ut2, Ut3, Us, Uls, Su4 and Slu of the KA5 classification.

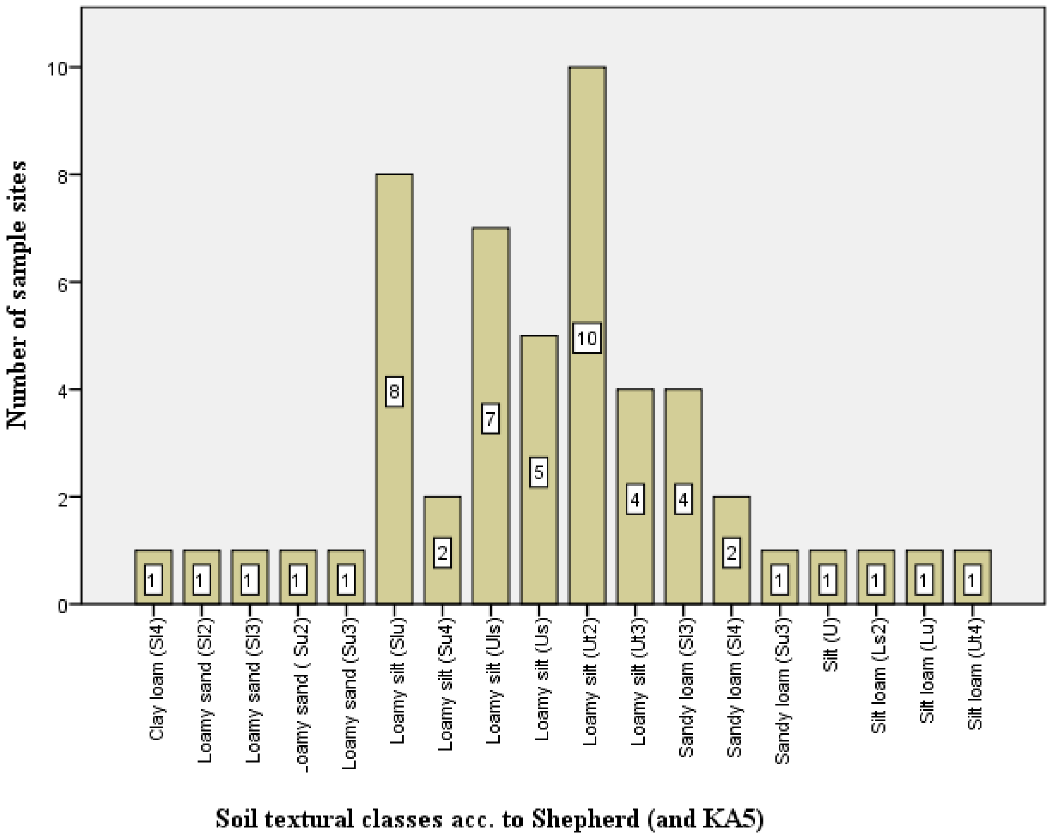

Figure 14: Outcomes of the topsoil texture analysis

4.4.2 Bulk density

The bulk density could be determined for 82 out of 104 samples. The high number of undetermined values, making up more than 20 % of the overall sample number, is due to difficulties during the sampling process in the field. The used soil core sampler could not be applied at all sample sites according to the descriptions given in chapter 3.2.4, as often a high amount of coarse material denied the application of the instrument. In these cases only a sample of undefined volume was taken to allow for the conduction of the other laboratory analyses, e.g. the analysis of the soil texture composition.

During the first assessment period the minimum BD value measured was 0,77 Mg/m³ and the maximum BD value measured was 1,38 Mg/m³. For the second assessment period the minimum value was slightly lower, at 0,72 Mg/m³, and the maximum measured value was slightly higher, at 1,52 Mg/m³. A moderate correlation of the BD values with the C_{org} values could be noticed for both periods. With a decrease in BD the measured C_{org} values increased. The spearman's ρ coefficient of this correlation was calculated to ρ=-.67 (first assessment period) and to ρ=-.71 (second assessment), both at a .01 significance level.

Looking at the data subdivided according to the different pasture management units it can be stated, that on average the BD was slightly lower at plots situated in the summer pasture unit (average BD 0,9 Mg/m³) than at plots in the winter/all-year pastures units (average BD 1,1 Mg/m³).

4.4.3 Soil moisture content and chemical soil properties

Due to the same reasons as for the analysis of the BD, the soil moisture content could also only be determined for 82 out of the104 samples. The measured soil moisture values lay between 7,8 Vol.-% and 49,8 Vol.-% for the first measurement period and lay between 7,6 Vol.-% and 44,6 Vol.-% for the second measurement period. In the boxplot (see figure 15) it can be seen, that only at two sample sites (A13201, A13203), the soil moisture content was high in comparison with the other measured values.

These two concerning plots were situated in the topographical position "valley bottom" close to a river. Taking these outliers out of the average value calculation, the respecting values dropped to 17,2 Vol.-% and 16,2 Vol.-% for the first and second assessment period. As these values already indicate, there was no significant change recorded in the soil moisture content between the first and the second assessment period. The change in the soil moisture content at the different sample ranged between 0,2 Vol.-% and 13,7 Vol.-%.

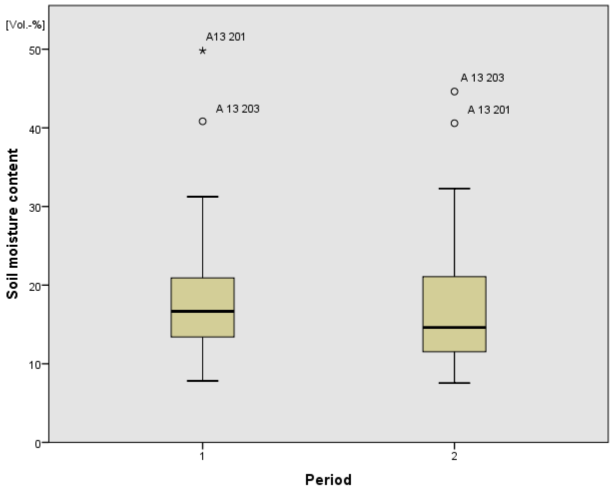

Figure 15: Boxplot of the measured soil moisture content values [Vol.-%] for the first and the second assessment period

The measured pH values, analysed only for the first assessment period, had a small range, with all values lying between 6,0 and 7,8.

The results of the C_t-, C_{org}- and N_t analysis are summarised in Table 9. The examination of the measurement results of the C_t-, C_{org}- and N_t content with regards to the different pasture management units revealed, that the average C_t-contents are equal in both areas. In contrast to that the C_{org}- and N_t values differed strongly. While in the winter/all-year pasture units the C_{org}- and N_t values were 2,1 % and 0,23 % on average, the respective values were almost twice as high (4,0 % and 0,45 %) for the samples taken in the summer pasture unit. This correlation leads to an almost equal C_{org} to N_t-ratio in both management units. A negative, moderate correlation between the pH values and the C_{org}-contents could be observed and proofed, with a calculated spearman's rho values of ρ=-.53 and ρ=-.57 at a .01 significance level.

Table 9: Characteristic values of the C_t-, C_{org}- and N_t –measurements

	Soil C_t content [%]	Soil C_{org} content [%]	Soil N_t content [%]	Soil C_{org}/N_t ratio
Number of analysed samples	103	102	103	102
Minimum	1,57	0,14	0,15	4,43
Maximum	8,59	7,07	0.77	13,66

4.4.4 Penetrometer

Out of 416 recorded measurements of soil resistance to penetration (104 sample sites, with a four time measurement repetition) only 134 could be successfully performed. In this context the term "successful" describes the reaching of the full measuring depth of 0,5 m. The obtained numerical results ranged from a minimum of 50 N/cm² (+/- 15 % deviation caused by the measurement device) to a maximum of 800 N/cm² (+/- 8 % deviation caused by the measurement device).

A high variability of results could also be observed in the repeated measurements conducted at each soil sample site and thus even for data obtained from within a relatively small area. This is shown through the overall number of sites, where a repetition of four consecutive measurements down to the aimed measurement depth of 0,5 m was possible, which summed up to only 13 sites. For these sites the results were found to be sufficiently robust to serve as basis for the calculation of penetrometer charts (see file "Penetrometer charts" on the CD). In the charts the average penetration resistance (N/cm²) of the four performed measurements is shown. The error bars indicate the corresponding maximum and minimum resistance values measured in the specific depth (given in cm). It can be observed that the measured values only in rare cases exceed 300 N/cm², which would indicated a significant hampering of plant root development. A compacted layer in the depth < 20 cm can only be predicted for the sample sites 13B401 and 13B406, which are both located in the subarea Karatal (see figure 16). For all other sites a slight increase in penetration resistance can be observed in the depth of 10 cm (see file "Penetrometer charts" on the CD).

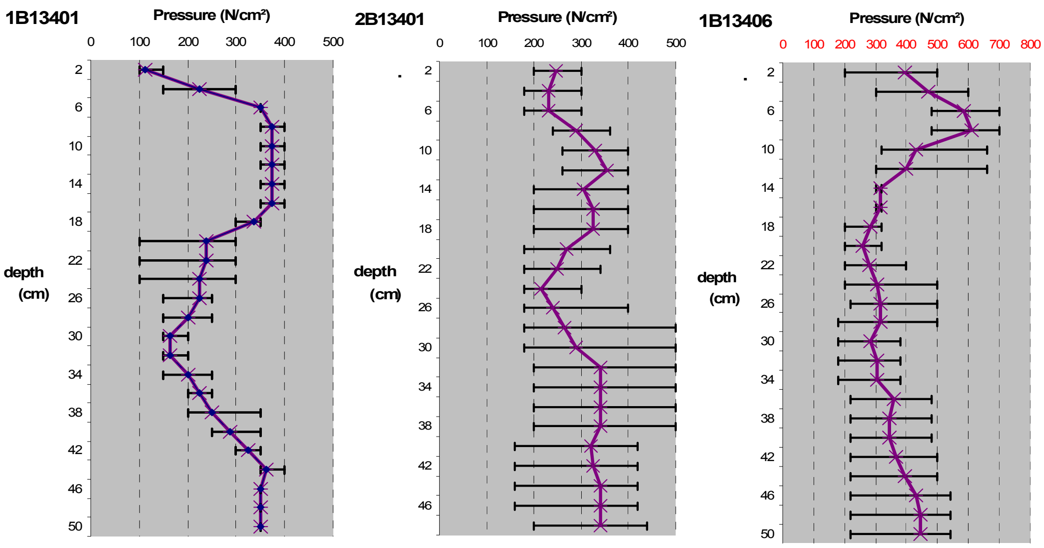

Figure 16: Penetration charts of the sample sites 13B401 and 13B406

The measurement results of the MPR and depth to MPR were grouped according to the depth they occurred in and according to the period they were measured in (see figure 17). A high variability of the results can be observed in both data sets.
The obtained MPR values ranged between 130 N/cm² and 800 N/cm² for the first measurement period and between 120 N/cm² and 700 N/cm² for the second period (see figure 17 for details). The median was at 400 N/cm².
The measured values indicate a significant hampering of plant root growth in the upper soil layers, as the observed measured values often exceed the threshold values of 300 N/cm². A difference in the MPR-values with regards to the different pasture management units could not be made out.

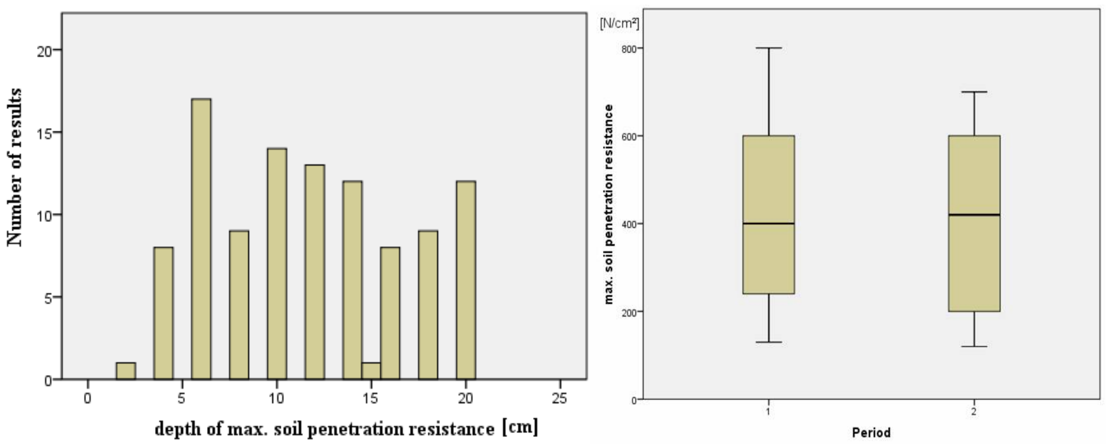

Figure 17: 1. Number of MPR values in the depth to 20 cm; 2. Boxplots of the MPR values of the first and the second assessment period

A negative moderate correlation between the MPR values and the soil moisture levels is indicated by spearman's rho values of ρ=-.638 (first assessment) and ρ=-.562 (second assessment), both at a .01 significance level. The MPR values were as well negatively, but weakly correlated to the C_{org}-content with values for spearman's rho of ρ=-.402 and ρ=-.351 at a .01 significance level. A moderate correlation was also found between the MPR values of the first measurement and the measured BD values (ρ=.518 at a .01 significance level).

4.4.5 Mini Disk Infiltrometer

The data obtained through the utilisation of the Mini Disk Infiltrometer allowed for the determination of the cumulative infiltration and of the infiltration rate (see file "Overview of results" in the folder "Infiltration" on the CD for details).

As the measurement was only repeated twice at each site, the calculation of the variance did not seem reasonable to analyse the data site specifically. Instead the calculation of the data ranges was chosen. The values of the infiltration rate showed a minimum of 14 mm/h and a maximum of 126 mm/h for the first assessment period. For the second measurement these parameters changed moderately: a minimum of 5 mm/h and a maximum of 110 mm/h was determined. In Figure 18 it can be seen, that there is not only a high variation of results regarding the outcomes of the measurements at the different sites, but also regarding the outcomes of the repeated measurements at the same sample site, which is represented through the high value of the calculated ranges.

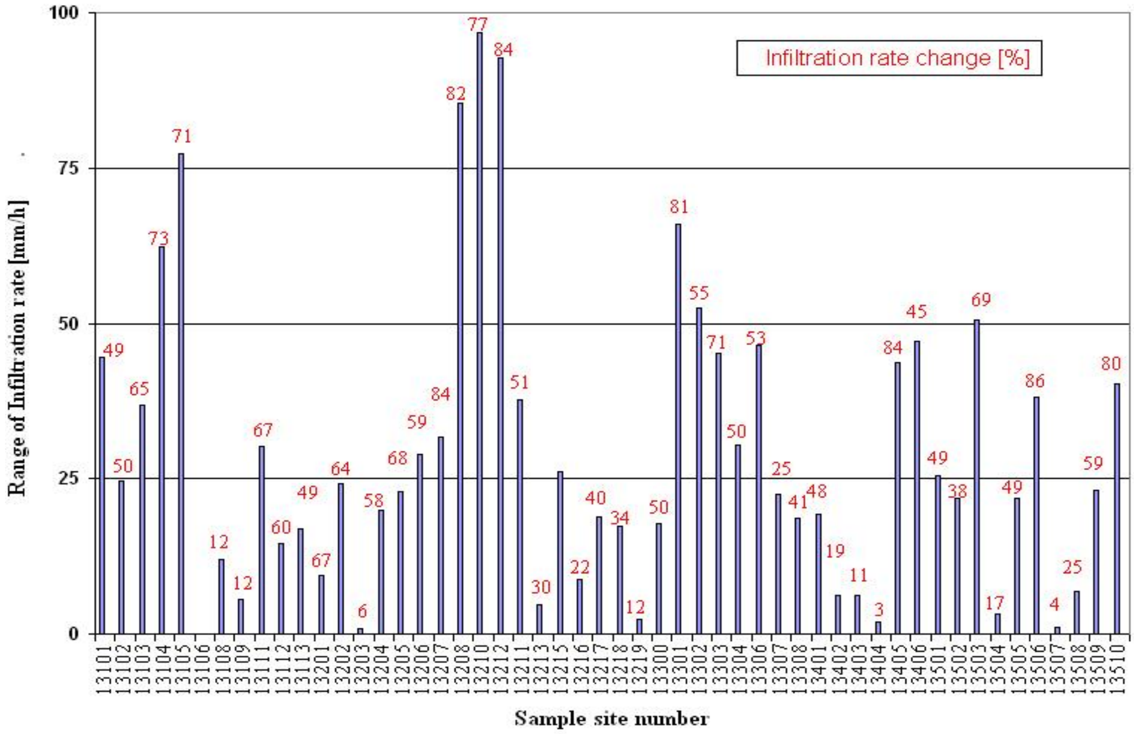

Figure 18: Ranges of the repeatingly measured infiltration rates

The latter is shown in the calculated ranges, which represent the differences in the measured infiltration rate of the first and second measurement. Looking at these changes of the infiltration rate given in percent (see red numbers in Figure 18) they can be classified as rather large. The aimed at cumulative infiltration volume of 15-20 ml (to allow an accurate calculation of the hydraulic conductivity; see chapter 3.2.6) was not always reached, as the schedule for the research on site was rather tight and did not allow for excessively long measurement processes. During the first assessment period in 77 % of the 52 measurements the named threshold value was reached. In the second assessment period this was only true for 61 % of the 51 measurements.

Nevertheless in a first approach all infiltration values were converted into values of unsaturated hydraulic conductivity (K_u) according to the method of ZHANG, using the "van Genuchten"-parameters. As negative hydraulic conductivity is a physical impossible, resulting negative values (this was the case for the sites A13104 and A13201) were excluded from the calculation. The remaining K_u values were recorded in the range of 0,4 mm/h and 45,2 mm/h. The average values of 7,6 mm/h and of 3,9 mm/h were calculated for the first and second measurement with standard deviation values of 8,4 and 3,6.

In a second approach the unsaturated hydraulic conductivity was only calculated for the sample sites, at which the cumulative infiltration was repeatly higher than the threshold value of 15 ml. The resulting average values rose to 10 mm/h and to 5,2 mm/h (with a standard deviation of 11 and 4) for the first and second assessment period. The range almost remained equal at 44 mm/h.

4.4.6 Vegetation data

All obtained results of the vegetation data analysis can be found in the file "Vegetation analyses results" on the CD. Regarding the aspect of the vegetation DM production the minimum vegetative DM production was measured and calculated to 2 dt/ha/a and the maximum vegetative DM production was determined to 15,4 dt/ha/a. The average of all measured values was 6,2 dt/ha/a. These results are based on the data obtained from the plots which were cut three times during the field research period, because these values do most likely depict a good estimate of the annual vegetative DM production.

Grouped by pasture management units the observation could be made that the measured average DM production in areas above 2.900 m (being 9,4 dt/ha/a) was considerably higher than the DM production below 2.900 m (being 5,5 dt/ha/a).

As a result of the qualitative and quantative vegetation assessment it can be stated, that the abundance of the plant species ranged between 7 and 36 on a 9 m² reference plot. The determined species number remained constant for the first and the second assessment period. Concerning the assessed dominance of the different species, a slight variation occurred between the two periods. During the first assessment period on 33 plots (62 % of the cases) a dominance of 25-50 % or higher of one species was determined, while this value was reached only on 25 plots (49 % of the cases) for the second period. Just like the dominance, the overall vegetative coverage (measured in %) also varied slightly between the first and the second period. The results measured during the first period ranged between 25 % and 90 % with an average of 57 % vegetative coverage, while for the second period the average vegetation cover was determined to be 52 % (range: 20 % to 90 %). A considerable difference between the plots situated in the different pasture management units could not be made out.

The effective rooting depth was measured for both periods in the range of 5 cm below the surface to 80 cm below the surface, which is equal to the classes Wp1 to Wp4 according to the KA5. In most cases, the results of the measurements conducted during the first and second assessment period were equal, but in in 15 cases (31 % of the measured plots) the measured effective rooting depth varied considerably. At four plots the measurement difference exceeded even 40 cm, which is equal to a change of two classification levels.

With regards to the results of the root density measurements a congruence of the results could be reported for the first and the second period. The counting of the roots led to results ranging between the classification levels Wg0 to Wg2 (0 to 4 thick roots) and Wf3 to Wf5 (6 to 50 fine roots).

4.4.7 Correlation of the VSA results to the soil data

For seven out of ten SQI indicators reference values existed. These indicators were: "soil texture", "soil structure", "soil porosity", "number and colour of soil mottles", "soil smell", "potential rooting depth" and "surface relief".

For the indicator "soil texture" a descriptive comparison of the results was chosen. As most frequent textural classification according to the "finger method" (SHEPHERD, 2000) "loamy silt" (67 % of the cases) was determined. This textural class is equivalent to the classifications "Slu", "Su4", "Uls", "Us", "Ut2", "Ut3" according to the KA5. Sites with the textural classes "sandy loam" or "loamy sand" according to SHEPHERD (2000), summed up to eleven, or 21 % of all cases. These outcomes corresponded with the laboratory results in 69 % of all cases for the first assessment and in 66 % of all cases for the second assessment period. Another 15 % respectively 16 % (first and second assessment period) of all cases were determined as "neighboring textural class" (leading to an estimation error of 0,5 points with regards to the VSA scoring scale). With the knowledge of the laboratory results the most frequent error, which occurred during the field assessment regarding the indicator "soil texture", could be determined as the confusion of the textural class "sandy loam" with the textural class "loamy sand", which occurred in 10 % of all cases. In how far further correlations between the VSA indicators and the soil data could be proofed through the calculation of the correlation coefficient τ is summarised in table 10.

Table 10: Correlation of VSA indicators the soil data

	Indicator		Bulk density [Mg/cm^3]	Silt [%]	Clay [%]	MPR [N/cm^2]	Infilt. Rate [mm/h]	Ku [mm/h]	Soil H_20 [%]	C_{org} [%]	C_{org} to N ratio
1. Period	VSA score soil structure	Kendall's tau	-,065	,224	,395	-,166	,070	-0,272	,117	-,045	,004
		Sig. (1-sited)	,299	,029	,000	,081	,274	,007	,173	,348	,487
		No. of cases	40	44	44	45	45	52	40	45	45
2. Period	VSA score soil structure	Kendall's tau	-,186	,003	,164	-,183	,197	,100	,022	,080	-,137
		Sig. (1-sited)	,068	,490	,099	,071	,057	,192	,429	,261	,135
		No. of cases	39	39	39	40	39	48	39	39	39
1. Period	VSA score porosity	Kendall's tau	-,329	,069	,244	-,406	-,203	-0,196	0,41	,307	,055
		Sig. (1-sited)	,003	,261	,013	,000	,028	,033	,000	,002	,302
		No. of cases	42	52	52	53	53	52	42	53	53
2. Period	VSA score porosity	Kendall's tau	-,225	,135	,031	-,378	,029	-,113	,101	,124	-,295
		Sig. (1-sited)	,035	,130	,401	,001	,405	,177	,209	,149	,006
		No. of cases	39	42	42	43	42	40	39	42	42
1. Period	VSA score no. and colour of soil mottles	Kendall's tau	-,236	,314	,079	-,167	-,021	-,137	0,21	,099	-,065
		Sig. (1-sited)	,034	,003	,251	,077	,427	,115	,049	,191	,284
		No. of cases	42	52	52	53	53	52	42	53	53
2. Period	VSA score no. and colour of soil mottles	Kendall's tau		,273	,174	-,153	,020	-,155		,048	-,180
		Sig. (1-sited)		,011	,075	,102	,431	,099		,343	,065
		No. of cases	40	50	50	51	50	48	40	49	49
1. Period	VSA score soil smell	Kendall's tau	-,318	,118	,014	-,278	-,254	-,129	0,31	,319	-,055
		Sig. (1-sited)	,005	,143	,451	,007	,010	,121	,005	,002	,307
		No. of cases	42	52	52	53	53	52	42	53	53
2. Period	VSA score soil smell	Kendall's tau	-,281	,159	,041	-,314	,044	-,093	0,46	,401	-,137
		Sig. (1-sited)	,013	,080	,363	,003	,349	,210	,000	,000	,114
		No. of cases	40	50	50	51	50	48	40	49	49
1. Period	VSA score rooting depth	Kendall's tau	-,316	,154	,144	-,420	-,032	-,113	0,32	,150	,140
		Sig. (1-sited)	,004	,076	,094	,000	,382	,144	,003	,077	,092
		No. of cases	42	52	52	53	53	52	42	53	53
2. Period	VSA score rooting depth	Kendall's tau	-,141	,183	,043	-,536	,294	,116	,179	,249	-,083
		Sig. (1-sited)	,121	,044	,346	,000	,003	,142	,069	,010	,220
		No. of cases	40	50	50	51	50	48	40	49	49
1. Period	VSA score relief	Kendall's tau	-,320	,178	,020	-,229	-,070	-,060	0,32	,372	-,104
		Sig. (1-sited)	,004	,048	,428	,017	,253	,285	,004	,000	,160
		No. of cases	42	52	52	53	53	52	42	53	53
2. Period	VSA score relief	Kendall's tau	,045	,046	-,025	-,106	-,099	,030	,151	,125	-,071
		Sig. (1-sited)	,358	,338	,412	,174	,185	,396	,111	,132	,261
		No. of cases	40	50	50	51	50	48	40	49	49
1. Period	VSA score root length and density	Kendall's tau	-,391	,167	,050	-,453	-,093	-0,202	0,41	,249	,103
		Sig. (1-sited)	,001	,061	,323	,000	,190	,030	,000	,009	,166
		No. of cases	42	52	52	53	53	52	42	53	53
2. Period	VSA score root length and density	Kendall's tau	-,334	,183	-,117	-,462	,180	,130	0,31	,443	-,136
		Sig. (1-sited)	,003	,048	,148	,000	,049	,122	,006	,000	,110
		No. of cases	40	50	50	51	50	48	40	49	49

expected correlation

correlation reported to be approved in SHEPHERD (2003a)

weak to moderate correlation found

4.4.8 Correlation of the VSA results to the vegetation data

Out of the ten PPI indicators for two indicators, the "root length and root density" and the "pasture growth", reference values existed. While in the preceding subchapter the SQI indicators were only examined on possible correlations to the soil data, the named PPI indicators were examined with regards to both measured data sets: the vegetation and the soil data. For the results of the VSA indicator "pasture growth" no correlation to the soil and vegetation data could be proofed through the calculation of the correlation coefficient τ. In contrast to that for the indicator "root length and root density" correlation proofing results could be obtained, which are listed in table 10.

As the vegetative DM production can be regarded as one of the key parameters in the evaluation of a pasture management system, the correlation of this parameter to the SQI and the PPI final results were additionally analysed. The results are shown in table 11. It can be seen that the SQI depicts the vegetative DM production weakly to moderately. Furthermore, through the calculation of the correlation coefficient τ, a constant moderate correlation of the vegetative DM production to the PPI could be determined for both assessment periods.

Table 11: Correlations SQI and PPI results to the measured vegetative DM production

	Index		Vegetative DM production	Index	Vegetative DM production
1. Period	SQI	Kendall's tau	,433	PPI	,590
		Sig. (1-sited)	,010		,010
		No. of cases	53		53
2. Period	SQI	Kendall's tau	,501	PPI	,624
		Sig. (1-sited)	,010		,010
		No. of cases	51		51

4.5 Summary of the results

In the beginning of this chapter it was mentioned, that the results of the research work can be devided into three parts. In the summary of the chapter the same structure will be used. Regarding the first part, the main results obtained through the VSA method application were:

- The final SQI and PPI scores were similar for both assessment periods.
- The pasture management unit "summer pasture" was rated better than the winter/all-year pasture units.
- 17 out of 20 VSA indicators could be applied/rated under the given site conditions; eleven of them only under diffiulties (see table 12).

The second part of the results can be summarised as follows for the MSQR:

- Respectively, the MSQR basic soil scores and the SQR scores were similar for both assessment periods.
- 14 out of 21 MSQR indicators could be applied/rated under the given site conditions; five of them only under difficulties (see table 12).

And for the method acc. Etzold:

- The results of site assessments according to the method by Etzold are similar for both assessment periods.
- 15 out of 16 indicators according to the method by Etzold could be applied/rated under the given site conditions, two of them only under difficulties (see table 12).

The summary of the third part contains the results of the standard field measurements and of the laboratory-based analyses, which were:

- The topsoil texture in the research area was characterised by high contents of silt.
- The BD ranged between 0,72 Mg/m³ and 1,52 Mg/m³.
- The measured soil moisture content remained constant for both assessment periods.
- In the majority of the cases the soil of the upper layer was charaterised by a high C_{org}-content and a slightly alkaine soil reaction.
- The measured MPR values indicated a significant hampering of plant root growth in the upper soil layers.
- The measured infiltration rate and the obtained K_u-values varied considerably (between the different research periods and assessment sites).

- The annual DM production was determined to a minimum of 2 dt/ha/a and to a maximum of 15,4 dt/ha/a. The higher results were obtained in the management units"summer pasture".

The found correlations of these data sets with the VSA indicator values, can be summarised as:

- For seven out of ten SQI indicators reference values existed, while this was only true for two PPI indicators.
- Significant, weak to moderate correlations could be obtained through the calculation of the Kendall's tau coefficient for the indicators results of:
  - "Soil porosity" (correlated with the measured MPR results),
  - "Soil smell" (correlated with the measured soil moisture- and C_{org}-contents),
  - "Potential rooting depth" (correlated with the MPR results),
  - "Root length and root density" (correlated with the BD and MPR results, and with the measured soil moisture content).

Table 12: Evaluation of the indicator applicability under the specific site conditions in Kyrgyzstan

Visual Soil Assesment		**Müncheberg Soil Quality Rating**		**Method according to Etzold (2010)**	
Soil Quality Index	Plant Performance Index	Basic indicators	Hazard indicators	Soil Erosion Index	Pasture Degradation Index
Soil texture	Pasture quality (Brix value)	Soil texture/substrate	Contamination	Inclination a	Bare soil
Soil structure	Clover nodules	Depth of A horizon or depth of humic soil	Salinisation	Altitude	Rubble/scree
Soil porosity	Weeds	Soil structure	Sodification	Inclination b	Rocks
Number and colour of soil mottles	Pasture growth	Subsoil compaction	Acidification	Aspect	Cattle tracks
Soil colour	**Pasture colour and growth relative to urine patches**	Rooting depth and depth of biological activity	Low total nutrient status	Topographic position	Erosion tracks
Earthworms	**Pasture utilisation**	Profile available water	Soil depth above hard rock	Solpe configuration	Browsing tracks
Soil smell	**Root length and root density**	Wetness and ponding	Drought	Bedrock	Cover grazing indicator species
Potential rooting depth	**Area of bare ground**	Slope and relief	Flooding and extreme waterlogging		Flowering plants
Surface ponding	**Drought stress**		Steep slope		Number of plant species
Surface relief	Production costs to maintain stock-carrying capacity		Rock at surface		
			High percentage of coarse soil texture fragments		
			Unsuitable soil thermal regime		
			Miscellaneaous hazards		

Could not be applied in the field
Could be applied in the field, but with difficulties **(in bold letters: due to assessment time)**
Could be applied in the field

5 Discussion

In this chapter a critical interpretation and evaluation of the in chapter 4 presented results is given. This discussion will be led with a special focus on the research question, which was presented in chapter 1. This leading research question was:
Is the Visual Soil Assessment method for pastoral grazing (according to SHEPHERD, 2009) fully applicable under the given specific site conditions in Kyrgyzstan?
The answer to this question will also include suggestions on how further research could lead towards the provision of a suitable, reliable and defensible visual site assessment method under the given site specific conditions.

5.1 Soil and vegetation data

Previous to a detailed examination of the visually assessed data, the plausibility of the measured soil and vegetation data shall be discussed in this subchapter. This change in the structure of the thesis is necessary, as the results of standard field and laboratory-based methods are used as reference in the succeeding subchapters. In order to serve as a reliable reference base, the plausibility of the measured soil and vegetation needs to be discussed first.

5.1.1 Bulk density

The measured and calculated BD, with a minimum of 0,72 Mg/m^3 and a maximum of 1,52 Mg/m^3 (see chapter 4.4.2), can be categorised as "low" to "very low" in reference to the values of BD found in the literature. In e.g. SCHEFFER et al. (2010) a typical BD range of 0,93 to 2,0 Mg/m^3 is defined for mineral soils (in the given reference, SCHEFFER et al. specified that "mineral soils" are characterised by a minimum C_{org}-content of < 2 %).
The C_{org}-content is a determining factor, which influences the BD of a soil highly (SCHEFFER et al., 2010). In MERRINGTON (2006) it is stated that an increase in the soil C_{org}-content improves "soil structure by decreasing BD, improving aggregate stability, increasing pore size and the proportion of air-filled pore space" (p. 26). The determined relationship between the C_{org}-content and the BD for mineral soils in the United Kingdom (UK) is shown in figure 19. It can be seen, that there is a constant non-linear decline in BD as the C_{org}-content increases.

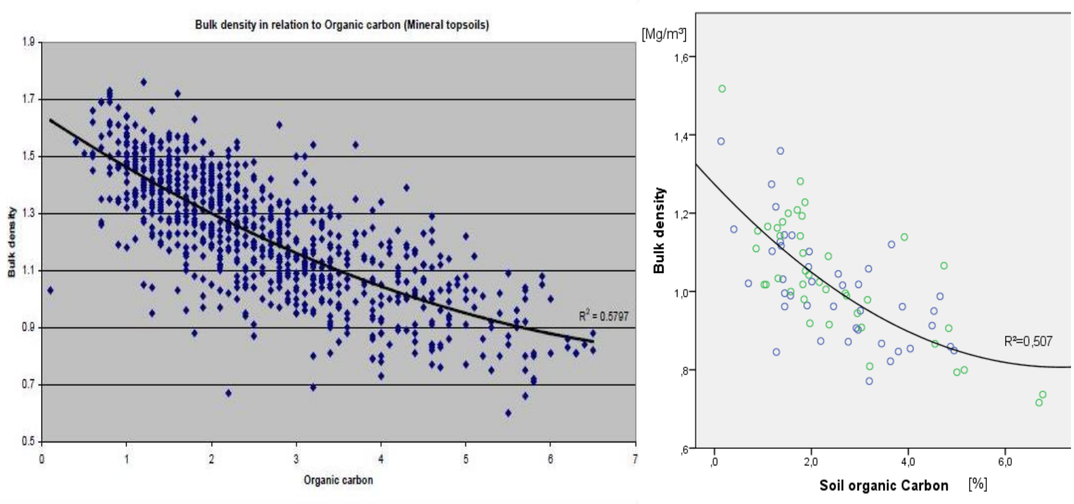

Figure 19: 1. Relationship between soil C_{org}-content [%] and BD [Mg/m³] for mineral topsoils in the UK (MERRINGTON, 2006), 2. Relationship between measured soil C_{org}-content [%] and measured BD [Mg/m³] in the research area

In 70 % of all analysed soil samples the C_{org}-content exceeded 2 %. A reducing influence of the C_{org}-content on the measured BD values can therefore be expected in most cases. Comparing the obtained relationship of the BD to the C_{org}-content (see figure 19) a high similarity to the outcomes of MERRINGTON (2006) can be noticed. Furthermore, SPARLING et al. (2000) found that the BD between different forms of land use decreases in the order: BD of agrarian soils > BD of soils under pine forest > BD of soils under pasture > BD of soils under native forest. This indicates that soil samples taken in a pasture area are more likely to be overall categorized as low to very low in comparison to reference values of BD found in the literature, which often refer to soils under arable land use. Despite the reducing influence of the C_{org}-content and also the effects of the land use form on the measured BD, still the measured outcomes are to be defined as "low" to "very low".

According to the findings in the literature an underestimation of the actual BD might have also occurred. In LOEHE (2006) a publication of SCHERZER et al. (2002) is cited, in which was shown that the soil core sample method systematically underestimates the BD, especially at sites where a high content of coarse material was measured. These findings are based on a comparison with the outcomes of the so called "PU-Schaum-Methode". In the actual research area a high content of coarse material also often occurred, which complicated the sampling process during the field research. Therefore the chosen "Soil Core sample method", as well as the influence of the coarse material, could have led to an underestimation of the actual BD.

5.1.2 Soil moisture content and chemical soil properties

The soil texture class, the BD and the C_{org}-content are key parameters, which determine the characteristics of the soil water household (SCHEFFER et al., 2010). The measured soil moisture content values need to be discussed taking these three parameters into account.

In general terms, for the topsoils in the research area it can be reported that: 1) the main soil texture class is loamy silt/silt loam, 2) the determined BD ranges between 0,72 Mg/m³ and 1,52 Mg/m³ and 3) C_{org}-content shows a minimum of 0,14 % and a maximum of 7,7 %; being higher than 2 % at 70 % of all sites. These measured values indicate that the topsoils present in the research area have a high to very high field capacity. The field capacity is defined as the "soil moisture state when, 48 hours after saturation or heavy rain, all downward movement of water has ceased" (EUROPEAN SOIL BUREAU (2006) in REGNER et al. 2008). The assumption that the soils have a high field capacity can be supported especially by the low measured BD values, which indicate that the pore volume in the regarded soils is high. This is a precondition for a high field capacity of a soil. Besides contributing to a high field capacity of the soil, loamy silt also shows the highest plant available water (PAW) values of all soil texture classes (see figure 20). For the assessment of the potential DM production of a site, the PAW is a determining factor. According to BLUME (2010) the PAW increases an additional 3-5 Vol.-%, if the C_{org}-content in the respecting soil is above 2 %. Concludingly the measured average soil moisture content values of 17,2 Vol.-% and 16,2 Vol.-% (for the first and respectively second assessment period) can be regarded as low in comparison to the possible field capacity of the topsoil present in the research area. The measured water content is still well above the permanent wilting point (PWP) and hence within the range of the PAW (see figure 20). Therefore the measured soil moisture contents should not have a reducing influence on the vegetative DM production at the sampled sites.

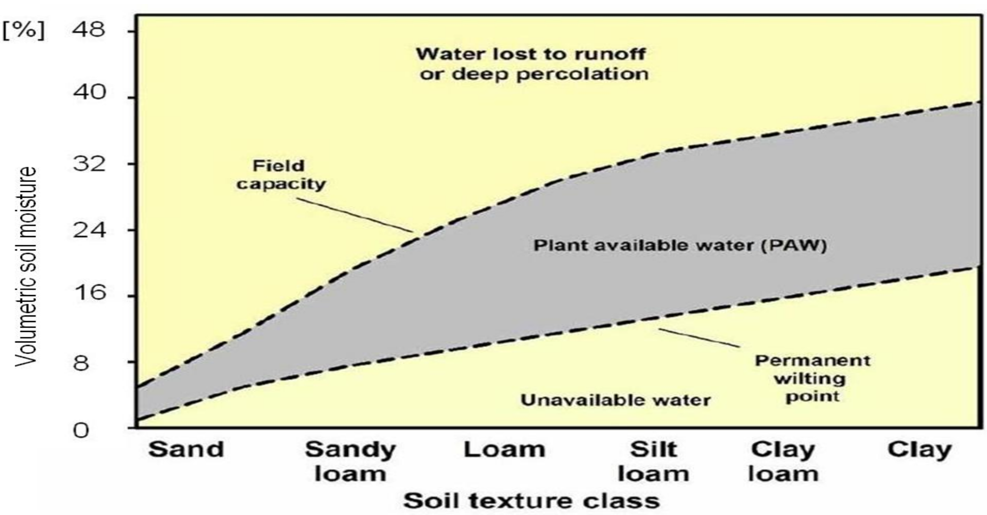

Figure 20: General relationship between PAW, soil field capacity, PWP and soil texutre class (ZOTARELLI, 2009)

For the measurements of the C_{org}- and N_t values and the C_{org}- to N_t ratio, as well as for the measured pH-values references could be found in SCHEFFER et al. (2010), HAZELTON et al. (2007), GISI (1997) and GOTTSCHLING (2006).

The measured C_{org}-values showed a minimum at 0,14 % and a maximum at 7,7 %. In reference to the general ratings shown in table 13, the evaluation can therefore range from "extremely low" to "very high". It was found as well, that in 70 % of all analysed soil samples the C_{org}-content exceeded 2 %. Therefore the most part of the samples could be evaluated of having a "high" content of C_{org}. This would implicate that the topsoils also have a good structural condition and stability (see table 13).

Table 13: The rating of soil organic matter and the relationship of soil organic matter to soil physical properties for soils that are light-textured (sand loams, loams) (EMERSON 1991 in HAZELTON et al., 2007)

Level of organic carbon % (g/100 g)	Rating	Interpretation
<0.40	extremely low	Subsoils or severely eroded, degraded surface soils.
0.40–0.60	very low	Very poor structural condition, very low structural stability.
0.60–1.00	low	Poor to moderate structural condition, low to moderate structural stability.
1.00–1.80	moderate	Average structural condition, average structural stability.
1.80–3.00	high	Good structural condition, high structural stability.
>3.00	very high	Good structural condition, high structural stability and soils probably water repellent.

A more specific evaluation of whether these values are high or low for the regarded area, "needs to take account of the potential of the area to build up soil carbon, based on the potential of biomass production and the potential for organic matter decomposition, which is primarily dependent on rainfall, evaporation and temperature" (HAZELTON et al., 2007). In his publication, in which different classification approaches for the soils in Kyrgyzstan are discussed, GOTTSCHLING (2006) evaluated soils with C_{org}-contents of 1,5 % to 2,5 % as "weakly humic" and soil with C_{org}-contents of 2,5 % to 4 % as "moderately humic". This indicates, that the C_{org}-contents under comparable conditions (rainfall, evaporation and temperature) are in general high. This, in turn, implicates the need to down-rate the evaluation to "weakly humic" for the obtained C_{org}-values.
According to SCHEFFER et al. (2010) the N_t-content in the Ah-horizon of mineral soils under pasture usage typical ranges between 2 to 6 g N_t per kg soil, which is equal to 0,2 to 0,6 %. The measured values fall for the most part into this range. In accordance to HAZELTON et al. (2007), this value is to be evaluated as a "medium" to "high" content of N_t.
The C to N ratio for mineral soils can take on values of 8 to 30 (GISI, 1997). Of this range, the values 10 to 15 are typical for soils under pasture usage in areas of continental climate. The measured average value of 9 is slightly below this range, but can be evaluated as still in good accordance with the values found in literature.
The measured pH values ranged between 6,0 and 7,8, which is almost equal to the range of the pH optimum for many different processes (e.g. humification, re-formation of minerals) (GISI, 1997). This range can be distinguished in "slightly acid" (pH value 6,1-6,5), "neutral" (6,6 to 7,3) and "midly alkaline" (7,4 to 7,8) (see HAZELTON et al., 2007). Under arid conditions, which are dominate in the research area, a neutral to midly alkaline pH value is typical (SCHEFFER et al., 2007). This is also a good precondition for the land use type "pasture and forage".

5.1.3 Penetrometer

The outcomes of the soil resistance to penetration measurement have to be regarded as incomplete, because the measurement process could not be successfully conducted at most of the sample sites. The reason for that was an exceedance of the maximum value, which ensures a safe devise utilisation. Therefore only for 13 out of 104 sites a calculation of penetrometer charts could be performed. As a possible causing factor a high content of coarse material in the soil matrix is supposed. This assumption is supported by the visual site appraisal and proofed through the measured data on the content of coarse material. The effects that the coarse material had on the measurement process is expressed in the high variability of the overall measurement results and also in the measured MPR values.

In O'SULLIVAN et al. (1987) it is reported that a high variability in the outcomes is quite common for a point measurement method, such as the resistance to penetration measurement is. In their paper O'SULLIVAN et al. (1987) illustrate that by stating: "The presence of stones increases the mean and standard deviation and may introduce unrepresentative extreme values into the data" (p. 137). In the same paper it was furthermore found that "the number of abandoned penetrations (attempts) becomes unacceptably high (more than about five attempts for each 450 mm penetration depth), when the content of stones greater than 10 mm diameter exceeds about 25 % by volume" (p. 138). This threshold value regarding the coarse material content given by O'SULLIVAN et al. was exceeded at many sampled sites. Therefore the measurement results seem rather to depict a high content of coarse soil fragments in the soil matrix than to show compacted layers or specific zones of soil compaction (which may have influence on the growing circumstances of the flora in situ).

In literature it is frequently stated that measurement results of soil resistance to penetration can vary significantly with the soil water content (e.g. MOELLER (2007), KIRKHAM (2004), LAPEN et al. (2004)). The "effects of the soil water content on measured soil resistance to penetration can [even] mask or confound interpretations of (treatment) effects on soil strength" (LAPEN et al., 2004, p. 51). In the given case the moisture content almost did not change (see chapter 4.4.3) over the whole research period. Therefore it can be assumed that a comparability of the results is given.

As for the interpretation of the MPR values and the measured depth of MPR, it has to be acknowledged, that the chosen method approach, which was used initially in stone-free soils (cf. NEWELL-PRICE et al., 2013) cannot be used in stony soils. The obtained high measured values do not necessary reflect soil strength, as coarse material is more likely to be the causing factor of the obtained MPR values. Therefore the MPR values do not indicate zones of maximum impedance, through which a root must pass before growing into a deeper layer, since roots can grow around stones (O'SULLIVAN et al., 1987). Therefore the MPR can also not be used to describe the circumstances of root growth of the flora in situ.

MUELLER et al. (2014) even questions the overall suitability of the penetrometer measurement to characterise the soil surface strength in pasture areas. In their book

"Novel Measurement and Assessment Tools for Monitoring and Management of Land and Water Resources in Agricultural Landscapes of Central Asia", MUELLER et al. propose that "measuring the sinking depth of a cone of defined weight and dimensions and calculating the cone resistance is more relevant to soil surface processes like stability against hooves of animals, sinking of tires or stability of crusts" (MUELLER et al., 2014, p. 202).

5.1.4 Infiltrometer

A high to very high variability in the infiltration data was observed during the field measurement as well as during the calculation and revision of the results. Possible causing factors, which also could be possible causes of error, were already identified during the field measurement process. In the course of the field measurements especially the inhomogeneity of the soil surface was recognized as such a factor. In the two pictures of figure 21 conditions are shown, which were often encountered during the research work. The first picture shows how high amounts of coarse material on the soil surface and an overall hard surface condition often impeded an appropriate placement of the infiltrometer. In such cases, it is advised in DECAGON DEVICES (2012) to apply "a thin layer of fine silica sand or diatomaceous earth [...] directly underneath the infiltrometer's stainless steel disk" (p. 12). A drawback of the use of such a material though, is an interference with the measurements, especially in the early stages of infiltration, leading to inaccurate sorptivity values (MINASNY, 2000). Due to this aspect and the limited availability of silica sand nor diatomaceous earth during the research period, a spot of placement for the infiltrometer was chosen to reach maximal contact between disk and soil surface, without using contact material and without disturbing the surface crust. The latter was necessary, because the measured values were supposed to reflect the infiltration procedure during/after a rainfall event, so that the measurement results could serve as reference values for the indicator "surface ponding". The inhomogeneity of the soil surface was not always caused by coarse material, which can be seen in the second picture of figure 21. Cracks in the soil surface due to dry weather and dry soil conditions were also often encountered. Under such inhomogen conditions BLUME (2010) recommends to repeat the infiltration measurement a minimum of 3 to 5 times to account for the natural variability of the measurement results. Due to the limited timeframe of the research period, the measurement could only be repeated twice though.

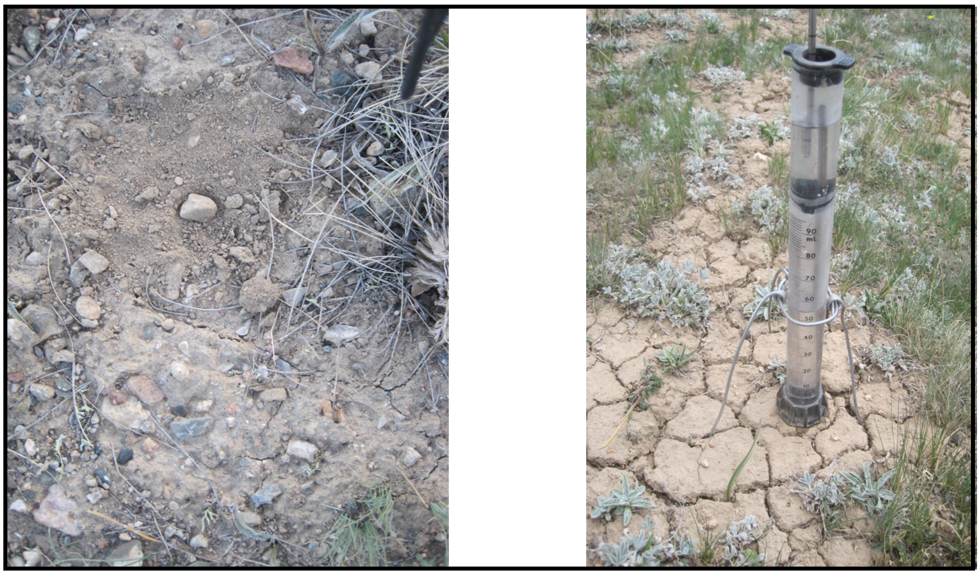

Figure 21: Pictures of the soil surfaces structures in the research area; 1. Plot B13307; 2. Plot C13501

In the course of the measurement results revision and the comparison of the outcomes with results reported in literature the high variability was found to be in good accordance with the general valuation of the unsaturated hydraulic conductivity measurement. As hydraulic conductivity (at or near saturation) is highly variable in space (variations can be caused by changes in: soil type, porosity, pore connectivity, pore distribution, roots growth, land use, wheel traffic) and also in time (all above listed possible causing factors, except the soil type are changing in time) a high variability of measurement results is often reported (e.g. SCHEFFER et al., 2010 and SCHACK-KIRCHNER, 2006). Moreover, the high variability of results reported in literature is also due to the fact, that there is a large number of methods and devices for the determination of the unsaturated hydraulic conductivity of soils. Different methods and devices implement also different measurement principals, different sizes of infiltration surfaces and a different need for contact material, which all together lead to different measurement results. Due to all above mentioned reasons, there are no specific reference methods or reference values of hydraulic conductivity near saturation for the different soil types or soil textural classes, which could serve to validate the obtained results.

Nevertheless, it was attempted to find related measurement values in the literature, to at least be able to classify the obtained results. These ranged between 14 mm/h and 126 mm/h for the infiltration rate and averaged at 7,6 mm/h and 3,9 mm/h for the unsaturated hydraulic conductivity value "K_u" (measured at a -2 cm pressure head). In a first step the obtained results were compared against the reported values of a study conducted in a neighbouring region of the research area in Kyrgyzstan (see BECKER, 2012). In this study only the infiltration rates were presented, which were reported to be in a range of 420 to 2.040 mm/h. In comparison with these results, the obtained values are to be evaluated as "very low". As in the study by BECKER sufficient information is not given on the measurement process (including the missing specification on the pressure head value) and no conversion into K_u-values was performed, the conclusion of the comparison to these findings needs to be regarded as of rather little importance.

In a second step the obtained results were compared with K_f-values given in the literature, which were measured on soils composed of similar soil texture classes. As reference source the book of HAZELOT et al. (2007) was chosen, which deals with the interpretation of soil physical data. Due to the deliberate exclusion of larger pores from the infiltration process performed during the field work, the measured K_u-values can be expected to be generally lower than the K_f-values, which are measured on a soil composed of comparable soil texture. Looking at table 14 the results for loam, which was the dominant texture type in the research area, are given with K_f=20-120 mm/h.

Table 14: Typical values of saturated hydraulic conductivity based on texture and degree of structure (HAZELOT et al., 2007)

Texture	Structure	Infiltration	Permeability (mm/h.)
Sand	apedal	very rapid	>120 can be as high as >250
Sandy loam	weakly pedal	very rapid	>120
	apedal	rapid	60–120
Loam	peds evident	rapid	60–120
	weakly pedal	moderately rapid	20–60
	apedal	moderately rapid	20–60
Clay loam	peds evident	moderately rapid	20–70
	weakly pedal	moderate	5–20
	apedal	slow	2.5–5
Light clay	highly pedal	moderate	5–50*
	peds evident	slow	2.5–10
	weakly pedal	very slow	<2.5
Medium to heavy clay	highly pedal	low to moderate	2.5–50*
	peds evident	very slow	<5.0
	weakly pedal	very slow	<2.5
Clay	sodic and saline	moderate	8.0
	sodic	very slow	<2.5
	highly sodic	extremely slow	<1.0

The obtained K_u-values ranged between 4,7 and 125 mm/h and it can therefore be approximated, that the measured values were in a reasonable range.

5.1.5 Vegetation data

In the context of the conducted research work, the information on the vegetative DM production was of particular interest. This is due to the fact of it being a key parameter of a pasture management system design.

The process of the DM determination was described in chapter 3.2.7. The respecting measurement procedure was repeated three times on the same sample plots in an interval of one month. It is stated in FRANZ (1973) that the average vegetation period in the central Tian Shan is 160 days at a heights of 2.500 m a.s.l. and about 120 days in regions situated above 3.000 m a.s.l.. As the measurement did not cover the whole vegetation period, the obtained average DM production values (in dt/ha/a) need to be regarded as rough approximations. Furthermore, the sample plots were not protected against grazing in the interim time and hence unregistrated grazing events cannot be excluded. This contributes to the conclusion to regard the obtained data as rough estimates.

Comparing the results (average: 6,2 dt/ha/a, with a minimum of 2 dt/ha/a and a maximum of 15,4 dt/ha/a) with the values found in literature, the measured results can be classified as very high to implausibly high. In Table 2 the average DM pasture yields for the Kyrgyz Republic for the past 70 years were shown, which were measured by the the Kyrgyz Land Management Institute (Kyrgyzgiprozem). These values never exceeded 2,85 dt/ha/a during the named time period. For the pasture type "summer pasture" the reported maximum value was 3,35 dt/ha/a and hence also far below the obtained value of 15,4 dt/ha/a. BUSSLER (2010) and FITZHERBERT (2006) reported also almost equal values: 1 dt/ha/a to 2,7 dt/ha/a DM yield on winter pastures and 4,1 dt/ha/a DM yield on summer pastures.

The root density values of Wg0 to Wg2 and Wf3 to Wf5, which were measured in the depth of about 15 cm seem reasonable as the overall organic matter of many plant species growing on pastures (first and foremost of grasses) is bond to 50 to 80 % in the roots (SCHEFFER et al., 2010). It has to be acknowledged though that these values cannot be regarded as representative for larger areas. A non-uniform distribution of the vegetation cover made the choice of representative sampling areas difficult. The high variations in the surface vegetation coverage occurred in correspondence with high variations in the root density. This is also true for the rooting depth measurements. The results of this measurement range between 5 and 120 cm (Wp1 to Wp4 according to the KA5). The big variance in the results can be explained by the fact that the rooting depth is dependent on many different site specific factors, like the water- and nutrient availability and/or physical barriers (SCHEFFER et al., 2010), and therefore varies strongly even within small areas.

A detailed discussion of the results of the qualitative and quantative vegetation assessment was not possible within the framework of this master thesis. With references to GOTTSCHLING (2006) a rough classification of the determined features can be performed as follows: as the grasses are dominant and a > 50-90 % vegetative coverage in combination with a xeromorphic character of the vegetation is given, the vegetation formation could be classified as "steppe". In some areas, where the vegetation cover is reduced and dwarf shrubs appear in the species composition, the vegetation formation could be classified as "degraded steppe" (cf. GOTTSCHLING, 2006).

5.2 VSA Method

The results of the VSA method application showed that the method was not fully applicable under the given site conditions in the research area (see chapter 4.1). Besides the aspect of "reduced applicability" also the indicator scoring and the site ratings are critically reviewed in the following.

5.2.1 Method applicability

If the overall method applicability would be evaluated using the VSA rating scale, the suggested rating would be "moderate". This is due to the fact, that a number of indicators could only be evaluated in the field under difficulties and for some indicators an evaluation was not possible at all according to the proposed evaluation guidelines (see table 12 and chapter 4.1 for details).

Regarding the indicators "pasture colour and growth relative to urine patches", "pasture utilisation", "root length and root density", "area of bare ground" and "drought stress" (indicated through bold letters in Table 12) an appropriate application was impeded, because the field research time was limited to the summer season. Due to this, the assessment time did not correspond with the different measurement periods foreseen in the VSA field guide, which are distributed over the whole year. Consequently, these findings do not have an influence on the overall applicability rating of the method, but rather diminish the applicability for method users, who want to conduct the assessment at one point of time (e.g. extension workers).

In the literature only a rather general quote was found on the topic "applicability": In SHEPHERD (2003b) it is stated that the "VSA can (therefore) be used by farmers regardless of where they are and what their soil types are" (p. 115). This quote implies that an applicability of the VSA method is given regardless of the site conditions. The findings of the thesis at hand do not confirm this quote.

5.2.2 Indicator scoring

Besides the "moderate" applicability of the VSA method in the field, the scoring of some indicators did also not seem to be adapted to the field conditions found.
This was the case for the indicators "earthworms" and "pasture growth". In accordance with the numerical rating scale of the indicator "earthworms", an indicator score higher than zero is only obtained if a minimum of 15 earthworms can be found in a soil sample of the size of a cube of 200 mm. In the course of the field research the absolute maximum number of earthworms obtained in such a sample was 10 individuals. For this reason the VSA scores for the indicator "earthworms" given in the guide seem to overestimate the potential earthworm number in the research area.
The indicator "pasture growth", according to its given scaling also does not reflect the conditions in the field. According to the field guide, a score higher than 0 is only obtained if the threshold value of 7 t/ha/a DM production is exceeded. In the field the maximum measured DM production was 15,4 dt/ha/a.
In how far the other indicator scores correlated with the actual site conditions could be evaluated for seven indicators (see chapter 4.4.7 and table 10). In accordance with the descriptions published by SHEPHERD (2003a, 2003b, 2009) correlations were expected to be found between the measured soil data and certain indicators scores. The table cells that should contain such correlation results are indicated through a yellow background colouring. The orange background colour of some further cells indicates, that correlations between the respecting data were approved and published by SHEPHERD (2003a). In table 10, it can be seen that through the calculation of the correlation coefficient Kendall's tau almost none of the expected correlation could be approved. Especially the BD results were expected to correlate moderately to strongly to the soil structure and the soil porosity scores as described in the literature (see SHEPHERD, 2003a). In contrast, the weak correlation of the measured BD with the results of the indicator "root length and density" corresponded with the expectations based on the literature analysis. Also the expected correlations of the indicator "soil smell" with the soil moisture content and the C_{org}-content were met. The doubts

concerning the scoring procedure of this indicator (see chapter 4.1.1) are therefore to be dismissed.

As shown previously, the plausibility of the MPR results has to be strongly questioned. Due to this the calculated correlations of this parameter with the VSA indicators are not to be regarded as representative and will not be further discussed.

The low overall correlation between the different data sets indicates a disparity between the site descriptions based on the visually assessed data according to the VSA guide on the one hand and the measured data according to the used standard field methods on the other hand.

5.2.3 Site rating

In this discussion approach, the initial site ratings were looked at without taking the aspects discussed in the previous two subchapters into account.

The fact that the final SQI and PPI scores, as well as the derived SQA and PQA assessments were similar for both assessment periods can be interpreted as a result which indicates a high reliability of the VSA rating procedure. As the time in between the two assessment periods was quite short (one month), no major changes in the soil and plant properties (except for the pasture utilisation) were to be expected. This is in good accordance with the measured results of the soil and vegetation data analyses. Regarding the soil properties: besides the quasi stable soil physical properties (e.g. soil texture, soil structure), also important dynamic factors, like the soil moisture content, remained constant (see chapter 4.4). Regarding the plant properties: one of the key parameters, the vegetative DM production, in the evaluation of a pasture management system, was determined over the whole vegetative period and therefore one constant value was used for the two assessment periods.

The finding that the sample sites in the pasture management unit "summer pasture" were rated higher than the sample sites in "winter/all-year pasture" units is partly in good accordance with the results of the soil and vegetation data analyses: Regarding the aspect "soil" it was found that the average BD was lower in the "summer pasture" unit than in the winter/all-year pasture units. A better soil structure and a higher C_{org}-content in the summer pasture unit is therefore to be expected, which was confirmed by the findings. Regarding the aspect "plant" the findings of the average DM production are showing that the annual average DM production per ha was 1,7 times higher in summer pasture unit than in winter/all-year pasture units.

5.3 MSQR

The MSQR method was also not fully applicable under the given site conditions in the research area. As the method corresponds with the VSA method in parts, the occurring difficulties were similar during the application process in the field. Besides that the characteristics of the MSQR valuation process seemed to have a had a converging influence on the final SQR scores and assessments. All of these aspects shall be discussed in detail in the next three subchapters.

5.3.1 Applicability

The overall outcome of the applicability assessment could be rated as "moderate" according to the MSQR rating system.

For the most part of the indicators that "could not be applied in the field" (see table 12) the application impendence was due to a lack of explicitness of the soil and plant indications in the field. Therefore the indicators in question ("contamination", "salination", "sodification", "acidification" and "low total nutrient status") could not be interpreted visually. As the named indicators can also be assessed with the help of field measurement instruments (recommended in the MSQR field guide: probe for pH and electrical conductivity), a better equipment status would have increased the overall method applicability.

For the application of the indicators "soil thermal regime", "drought" and indirectly "profile available water" a good knowledge of the microclimate conditions in the area of interest is required. Especially for remote mountain areas this kind of information is often not accessible, due to the commonly tessellated character of the microclimate in these regions. Therefore the overall method applicability in such regions is reduced.

In contrast to the VSA method, the overall applicability of the MSQR method is not diminished due a dependency on various assessment periods.

5.3.2 Indicator scoring

Regarding the scoring of the indicator "soil structure", the results were already critically discussed in chapter 5.2.2, as the indicator scoring is equal for both the MSQR and VSA method.

The scoring of the soil indicator "depth of the A horizon/humic soil (d_h)" is dependent on the recognition of the humic soil horizon, which in turn is determined by a SOM content of > 4 %. The analysis of the C_{org}-content showed that at a majority of the sample sites (85 % of all sample sites) this threshold value was not exceeded in the soil layer of interest. The evaluated indicator scores of max. 1 are therefore justified. The scoring of the remaining 15 % of the sample sites also corresponded well with the measured field conditions: for 50 % of the remaining sites a score of 1,5 was assigned, which was validated by the measured SOM contents of > 4 % and a determined sufficient rooting depths at these sites.

In the aftermath of the fieldwork it was found out, that the scoring of the indicator "subsoil compaction" with reference to the orientation guide "subsoil compaction, particularly under grassland" was not appropriate under the given site conditions. In a personal correspondence, the author of the MSQR method stated that instead of using the references "hydromorphic features of the subsoil" (which are described in the orientation guide named above), in the given case the subsoil structure should have served as rating reference. Taking the shallow soil depth and the high coarse material content at many sites into account it can be assumed, that the issued subsoil compaction score of 2 (in more than 95 % of all cases) was in turn too high.

To affirm the scoring of the soil indicator "profile available water" the plant available water (PAW) values were calculated. These values were derived from the measured potential rooting depth and form the usable field capacity (nFK)-values of the determined soil types. Through the comparison of the calculated results with the values given in the orientation guide in the MSQR manual 65 % of all scores assessed in the field could be approved. For the remaining 35 % of the field assessments, the scoring error never exceeded 0,5 scoring points. Groundwater did to have a significant influence on the overall scoring, as groundwater occurrence was only measured at four sample sites. The resulting scores are still to be seen as rough estimates, as "in drier regions, many soils have a high water storage capacity, but this resource is not available as the store is not filled" (MUELLER, et al. 2007, p. 22).

Due to the specific MSQR evaluation system the score of a single hazard indicator can have a significant influence on the overall SQR outcome (see chapter 3.2.2). In the given case, this was especially true for the indicator "drought", which was the lowest scoring indicator at all sites. Out of all hazard indicators, the scoring of this indicator therefore needs to be discussed in detail: The indicator score of 0,5 was obtained with reference to the "de Martonne" aridity index. The data for the index calculation was approximated, as reliable climate data was not available. The numerical outcome of the "de Martonne" aridity index therefore also needs to be regarded as a rough approximate.

In a personal correspondence, Müller stated to have rated a sample site close to Bishkek (about 250 km north of the research area) with a "drought" score of 0,75 himself. This can be regarded as a vague approval of the estimated value.

5.3.3 Site rating

It was found that the MSQR basic soil scores and the SQR scores were similar for both assessment periods, which indicates an overall high reliability of the methods scoring and rating procedure (see chapter 5.2). With regards to the site rating results of the different management units: Slight changes in the respective site ratings could be observed, which suggests an appropriate sensitivity of the rating and scoring procedure, as changes in soil and plant parameters were also measured (see chapter 5.2).
Through a comparison of the different scores (the basic soil score and the SQR score), it can be observed that changes in soil parameters were well represented in the basic soil score. This is indicated by the broad range of the obtained basic soil assessment results (being from "poor" to "good"; see chapter 4.2). In contrast to that the performed valuation and calculation processes to obtain the SQR scores seem to have led to an insensitivity concerning differences in the site conditions on the local scale. The outcome of the "soil quality assessment" (derived from the SQR score) is identical for all sampled sites and describes the site condition overall as "very poor". This may be due to the fact that the SQR is supposed to reflect the soil qualities in relation to "the crop yield potential within climatic sub-zones" (MUELLER et al., 2007, p. 4). Therefore some of the used hazard indicators are scored in reference to global orientation guides, e.g. the indicator "drought". This leads to an up-scaling of the scoring, which allows the comparison of the results on a global level. On this level, e.g. the crop yield potential of pastures may range from 0 to >170 dt DM/ha/a (SHEPHERD, 2000). In contrast, the measured results of the vegetative DM production in the different management units ranged between 2 and 15 dt DM/ha/a. In consequence, due to the proportional small range in the measured vegetative DM production, the changes cannot reflected in the SQR score.

5.4 Method according to Etzold

The method according to Etzold could be applied well under the given field conditions. Also the indicator scoring could be performed in the majority of the cases without difficulties. These aspects as well as in how far the site ratings reflected the actual conditions in the field shall be discussed in the following subchapters.

5.4.1 Applicability

Out of 16 indicators, which are supposed to be scored according to the method of Etzold, 15 could be applied during the field assessment under the given site conditions (see table 12). As only for three indicators the assessment was associated with difficulties the overall outcome of the applicability assessment could be rated as "high" according to the methods specific rating system.

The occurring difficulties were for the most part due to a lack of information on the site specific conditions. These regarded especially the topics "geology" and "botany". If this information would have been available, the applicability of the method according to Etzold would have been fully given.

5.4.2 Indicator scoring

Just as the applicability in the field, the scoring categories of the different indicators also seemed to be well adapted to the field conditions found. Changes in the field conditions were reflected by changes in the respecting indicator scores. This is shown through a broad range of obtained outcomes, which reflects the variability in the found site conditions well. All scores of the SEI indicators are based directly on the measured field data through their conversion into numerical scores with the help of the scoring tables given in the field guide. The scores of the PDI indicators are based on the assessment of the respecting cover percentages and on the species number count in the sample area. For both data sets types, no standard field reference measurements are possible, as the data sets are already based on methods used in the standard field assessments. This also implies that a comparison to measured data could not be performed. Nevertheless, the indicator scores are perceived as very resilient, which is due to the fact that the assessment of the cover percentage as well as the species number count can be classified as simple and not prone to significant errors.

Two drawbacks of the given indicator scoring have to be named though: the scoring categories of the indicator "bedrock" are designed for a specific area (the south Caucasus). An adequate scoring of the indicator in other regions seems therefore not to be fully given. Furthermore the indicator scoring reference "soft" and "solid" are given without any further reference value, which makes the scoring quite vague.

The latter is also true for the indicator "flowering plants". In this case the indicator scoring values "few", "medium" and "a lot" are also given without any further reference value. This makes the scoring be dependent on the knowledge of a "normal state" in order to allow the demanded comparative score evaluation.

5.4.3 Site rating

The site rating according to the method of Etzold needs to be regarded for each of the obtained indices respectively.

The SEI reflects the potential erosion on a site and is rated on the basis of indicators through which non-dynamical site conditions are assessed (e.g. exposure, inclination). The equality of the obtained outcomes for the two different assessment periods therefore meets the expectations. This is also true for the different management units, as they did not differ (besides a difference in elevation), in a great extent in terms of non-dynamical site conditions.

The PDI reflects the current state of the pasture site, which in turn also includes dynamical site conditions. As only two of the indicators ("flowering plants" and "browsing tracks") take also seasonal dynamics into account inequalities in the outcomes were expected between the different pasture units, but not between the different assessment periods. This expectation was met.

5.5 Synthesis of the discussion

The moderate applicability of the VSA method and the low overall correlation between the indicator ratings and the measured data sets show that the VSA method can neither be fully applicated nor be verified as adapted to the specific site conditions in the research area. Besides the limited applicability of the different indicator assessment processes, the performance of the indicator rating in the research area was often connected with difficulties (see chapter 4.1). As some indicator ratings were not assessable at all (e.g. "soil colour" and "production costs to maintain stock-carrying capacity") also the overall indicator composition is to be questioned. In its given form the VSA method can therefore not be used as suitable, reliable and defensible visual site assessment method under the given site specific conditions.

The field research results showed, that the indicator sets of the conducted alternative visual field assessment methods are equally and even better applicable under the specific site conditions. The applicability of the MSQR method was found to be equal,

because a necessity to perform additional soil quality measurements is given to allow the rating of certain indicators. This underlines the aspect that the method is first and foremost designed for extension workers and for experienced soil scientists. Nevertheless, the overall indicator composition of the method seemed slightly better adapted and applicable in the research area than the VSA method.
The method according to Etzold is very well adapted to the given field conditions and showed the best applicability in comparison with the other two methods. Through slide adaptations to the specific conditions in the research area, a full applicability could be achieved. In such an adapted form the method could serve as suitable, reliable and defensible visual site assessment method under the given site specific conditions in good correspondence with the overall goals of the UPAGES project.

5.6 Methodical difficulties

In the course of the field work as well as during the valuation and discussion of the obtained data methodical difficulties were determined.
A major methodical difficulty and a possible source of error was that the assessments and measurements were carried out only two times in the rather short timeframe of four month. Due to this fact, the statistical significance is limited and the resilience of the data is reduced. This aspect has influence on the evaluation quality of the calculated correlations between the VSA indicator ratings and the measured data sets. To evaluate possible discrepancy between the measured data and the actual indicator outcomes with certainty, more resilient data sets are needed. In the given case, even though the results of the measured soil and vegetation data are evaluated as plausible through a comparison with the results found in literature, they do not necessarily reflect the actual site conditions in an appropriate accuracy. This can be explained by the fact that the outcomes of many measurements of soil quality dependent on "the time of year the sample was taken for analysis, the nature of the season, the soil water content, the sampling depth, and the instrumentation and laboratory methodology used" (SHEPHERD, 2003a, p.162) and may therefore vary. This reduces the resilience of the measured data sets. A reduction of data resilience was also induced through the fact that the visual assessment of the site properties might not have been performed in a right manner. In the beginning of the field work the author only had little experience in carrying out the visual site assessment methods. This was not seen as a drawback, because the methods (except the MSQR method) are designed to be as well performed

by unexperienced individuals. Nevertheless, indicator evaluation errors due to a subjective misinterpretation of the soil and plant properties can therefore not be excluded.

A second methodically difficulty was also connected to the approach of verifying the results of the visual assessment with measured site condition values. The choice of the standard field and laboratory-based methods for the assessment of the soil and the vegetation data was based on the aspect of "simplicity", both in the field equipment needed and in the associated field application processes. The expected field conditions (e.g. limited infrastructure for the transport of material and samples) and the research limitations (e.g. field assessment time) of the UPAGES framework were also taken into account. In how far the resulting composition of the chosen methods can depict the overall soil condition and plant performance precisely is to be questioned. Important aspects of the soil condition, like aggregate size distribution, air permeability, macroporosity and aggregate stability were not directly assessable by the chosen measurement methods. The close relationships between the visual scores and the laboratory-based measures of soil properties, which SHEPHERD (2003a) found, were largely based on results of the above listed aspects of soil condition. A comparison to these outcomes and the results obtained through the field work could therefore only be performed partly.

Additionally the performed measurement of soil resistance to penetration did not provide usable results under the specific site condition.

5.7 Further research questions

It was shown in the previous chapters, that the VSA method in its given form cannot be used as suitable, reliable and defensible visual site assessment method under the given site specific conditions. To reach the goal of providing such a visual site assessment method, which is adapted and applicable under the given specific site conditions, two approaches of further research are proposed.

On the one hand an approach of further research could be the adaptation of the VSA method to the site specific conditions. This could be realised through a change in the scoring descriptions or through a change in the overall indicator composition. To allow for an adaptation, a well-founded and more detailed site analysis and site monitoring in the research area is necessary. With regards to the obtained results, the following suggestions can be made:

- The indicators "soil colour" and "production costs to maintain stock-carrying capacity" are to be replaced/excluded.
- The reference species for the indicator "clover nodules" is to be changed (possible choice of a different leguminous plant as reference)
- The rating scales of the indicators "earthworms" and "pasture growth" are to be adapted.
- The indicator species choice of the different PQI indicators needs to be reviewed.

On the other hand further research on the adaptation of the method according to Etzold could also lead to the accomplishment of the UPAGES project goal. With regards to the above presented findings, the following suggestions for a method adaptation can be made:

- The indicator "bedrock" needs to be adapted to the site specific conditions, including the provision of an adapted assessment procedure
- The assessment description of the indicator "flowering plants" needs to be enhanced through the definition of threshold values or reference photographs.

The latter presented approach seems to be more appropriate and recommendable as the method according Etzold is already well applicable and adapted to the site specific conditions. To provide a suitable, reliable and defensible visual site assessment method only minor changes are necessary.

Further research on the MSQR method is not proposed in the given context, because the method is first and foremost designed for extension workers and for experienced soil scientists and therefore does not allow the land users themselves to analyse the pasture in use. The latter aspect is seen as a method characteristic, which is of high importance under the presented overall conditions in the kyrgyz agrarian sector (see chapter 3).

6 Summary

The master thesis at hand was written in the framework of the project "Utilisation and protection of agricultural ecosystems in Central Asian high mountains – case study Kyrgyz alpine pastures" (UPAGES), which aims to facilitate the productive utilisation of pastures in Kyrgyzstan and at the same time allow for their efficient protection. Within the project framework, the objective of the thesis was the provision of a suitable, reliable and defensible visual site assessment method under the given site specific conditions, which allows for an evaluation of the actual pasture condition. Furthermore this method is supposed to lead to a sensitisation of the land users concerning the topics "soil and pasture degradation" and to an awareness building concerning the need of a sustainable utilisation of the pasture areas. As potentially fitting method, the VSA method (developed in New Zealand) was chosen. A process of application and verification in the research area was conducted to answer the main research question posed in the context of this work. This research question was: "Is the Visual Soil Assessment method for pastoral grazing (according to SHEPHERD, 2009) fully applicable under the given specific site conditions in Kyrgyzstan?" The necessary field research to answer this question took place in a four-month period, during which the assessment process could be repeated twice. The assessment process consisted of the application of the VSA method and of two additional visual field methods in different pasture usage regimes present in the research area. The latter were conducted to test the applicability of possible alternative visual indicator sets. Standard field and laboratory-based methods for the assessment of soil and vegetation data were also applied in order to create a site related reference-data pool.

The VSA method was found to be moderately applicable under the specific site conditions. Furthermore the low overall correlation between the indicator ratings and the measured data sets led to the conclusion that the VSA method in its given form cannot be classified as suitable under the given site conditions. In contrast, the indicator sets of the conducted alternative visual field assessment methods were better applicable. The method according to Etzold showed the best applicability and suitability under the specific conditions in the research area. Through slight adaptations to the specific conditions a full applicability of this method in the research area could be achieved. To reach the UPAGES project goals, further research should therefore concentrate on this visual site assessment approach.

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Annexes

Table 15: Overview of political and economic transformations and the implications on pasturing and the ecology of pastures (BECKER, 2012)

	Pre-Soviet period	Soviet period	Post-Soviet period
(1) ECONOMY			
Economic system	Subsistence	Planned, USSR support and marketing channels	Market economy; subsistence, local markets
ownership	Genealogical groups	State and collective farms	Private, mainly small household enterprises
(2) PASTURING			
System	Nomadic	Transhumance	Transhumance
Movement, migration	Horizontal, vertical	Vertical, transport to remote pastures	Vertical
Winter	Winter pasture	Housing, fodder supply	Winter pasture, fodder supply
Spring, autumn	Spring-autumn pasture	Village pastures, short usage of spring-autumn pasture	Spring-autumn pasture
Summer	Summer pasture	Summer pasture	Summer pasture
Sheep	Fat tail meet sheep	Fine wool sheep	Fat tail meet sheep
(3) ECOLOCIGAL ASPECTS			
Limitation of flock sizes	Harsh winters	Forage supply	Socio-economic situation
Degradation	Natural balance	Summer pasture	Winter pasture, spring-autumn pasture

Table 16: Results of the MSQR method

	1. period				2. period			
Sample Site	Basic soil score	Basic soil assessment	SQR score	SQR assessment	Basic soil score	Basic soil assessment	SQR score	SQR assessment
A13 101	19,5	poor	9,75	very poor	19,5	poor	9,75	very poor
A13 102	23	moderate	6,9	very poor	26	moderate	7,8	very poor
A13 103	23	moderate	11,5	very poor	23,5	moderate	11,75	very poor
A13 104	21,5	moderate	10,75	very poor	20,5	moderate	10,25	very poor
A13 106	26,5	moderate	13,25	very poor	24,5	moderate	12,25	very poor
A13 108	22,5	moderate	11,25	very poor	21,5	moderate	10,75	very poor
A13 109	19	poor	9,5	very poor	20	moderate	10	very poor
A13 111	19	poor	3,8	very poor	19	poor	3,8	very poor
A13 112	13,5	poor	2,7	very poor	14	poor	2,8	very poor
A13 113	15,5	poor	3,1	very poor	16,5	poor	3,3	very poor
A13 201	28,5	good	14,25	very poor	26,5	moderate	13,25	very poor
A13 202	25,5	moderate	12,75	very poor	24,5	moderate	12,25	very poor
A13 203	29	good	14,5	very poor	29	good	14,5	very poor
A13 204	24	moderate	12	very poor	25	moderate	12,5	very poor
A13 205	23	moderate	11,5	very poor	25	moderate	12,5	very poor
A13 206	14,5	poor	2,9	very poor	13	poor	2,6	very poor
A13 207	18	poor	3,6	very poor	18,5	poor	3,7	very poor
A13 208	26,5	moderate	13,25	very poor	26,5	moderate	13,25	very poor
A13 210	20,5	moderate	10,25	very poor	20,5	moderate	10,25	very poor
A13 211	16,5	poor	8,25	very poor	16,5	poor	8,25	very poor
A13 212	18	poor	9	very poor	18	poor	9	very poor
A13 213	29	good	14,5	very poor	26,5	moderate	13,25	very poor
A13 215	24,5	moderate	12,25	very poor	24,5	moderate	12,25	very poor
A13 216	24,5	moderate	12,25	very poor	23,5	moderate	11,75	very poor
A13 217	26	moderate	13	very poor	26	moderate	13	very poor
A13 218	24	moderate	12	very poor	26	moderate	13	very poor
A13 219	23,5	moderate	11,75	very poor	22,5	moderate	11,25	very poor
B13 300	26,5	moderate	13,25	very poor	27	moderate	13,5	very poor
B13 301	23,5	moderate	11,75	very poor	23,5	moderate	11,75	very poor
B13 302	26	moderate	13	very poor	26,5	moderate	13,25	very poor
B13 303	17	poor	8,5	very poor	17,5	poor	8,75	very poor
B13 304	17	poor	5,1	very poor	17,5	poor	5,25	very poor
B13 306	15,5	poor	4,65	very poor	18	poor	5,4	very poor
B13 307	15,5	poor	4,65	very poor	16	poor	4,8	very poor
B13 308	17,5	poor	3,5	very poor	18	poor	3,6	very poor
B13 401	25,5	moderate	12,75	very poor	28	good	14	very poor
B13 402	21,5	moderate	10,75	very poor	23	moderate	11,5	very poor
B13 403	21,5	moderate	10,75	very poor	25,5	moderate	12,75	very poor
B13 404	22	moderate	11	very poor	23	moderate	11,5	very poor
B13 405	24	moderate	12	very poor	24	moderate	12	very poor
B13 406	25,5	moderate	12,75	very poor	23,5	moderate	11,75	very poor
C13 501	23,5	moderate	11,75	very poor	24,5	moderate	12,25	very poor
C13 502	25,5	moderate	12,75	very poor	27	moderate	13,5	very poor
C13 503	26,5	moderate	13,25	very poor	26	moderate	13	very poor
C13 504	25	moderate	12,5	very poor	24,5	moderate	12,25	very poor
C13 505	28,5	good	14,25	very poor	27,5	good	13,75	very poor
C13 506	21,5	moderate	10,75	very poor	22,5	moderate	11,25	very poor
C13 507	20	moderate	10	very poor	23	moderate	11,5	very poor
C13 508	24	moderate	12	very poor	24,5	moderate	12,25	very poor
C13 509	24,5	moderate	12,25	very poor	26	moderate	13	very poor
C13 510	21	moderate	10,5	very poor	23	moderate	11,5	very poor

Table 17: Results of the method according Etzold

	Susceptibility to Erosion-Index (SEI)				Pasture Degradation-Index (PDI)			
Sample site	1. period		2. period		1.period		2. period	
A13 101	50,0	medium risk	50,0	medium risk	48,8	medium	43,8	medium
A13 102	42,8	medium risk	42,8	medium risk	55,6	medium	53,1	medium
A13 103	38,3	medium risk	38,3	medium risk	45,0	medium	48,1	medium
A13 104	41,1	medium risk	41,1	medium risk	45,0	medium	45,0	medium
A13 106	70,6	low risk	70,6	low risk	53,8	medium	56,3	medium
A13 108	68,3	low risk	68,3	low risk	52,5	medium	50,0	medium
A13 109	61,1	medium risk	61,1	medium risk	36,3	medium	38,8	medium
A13 111	47,8	medium risk	47,8	medium risk	31,3	strong	31,3	strong
A13 112	48,3	medium risk	48,3	medium risk	25,0	strong	25,0	strong
A13 113	45,0	medium risk	45,0	medium risk	28,8	strong	26,3	strong
A13 201	80,6	low risk	80,6	low risk	68,8	low	71,9	low
A13 202	80,6	low risk	80,6	low risk	50,0	medium	55,6	medium
A13 203	74,4	low risk	74,4	low risk	55,0	medium	55,0	medium
A13 204	78,3	low risk	78,3	low risk	52,5	medium	52,5	medium
A13 205	62,2	medium risk	62,2	medium risk	57,5	medium	60,0	medium
A13 206	60,0	medium risk	60,0	medium risk	32,5	strong	37,5	medium
A13 207	42,8	medium risk	42,8	medium risk	30,0	strong	30,0	strong
A13 208	55,0	medium risk	55,0	medium risk	30,0	strong	42,5	medium
A13 210	72,8	low risk	72,8	low risk	56,3	medium	56,3	medium
A13 211	70,0	low risk	70,0	low risk	45,0	medium	45,0	medium
A13 212	76,1	low risk	76,1	low risk	47,5	medium	47,5	medium
A13 213	73,3	low risk	73,3	low risk	60,0	medium	65,0	medium
A13 215	43,9	medium risk	43,9	medium risk	48,1	medium	50,6	medium
A13 216	53,9	medium risk	53,9	medium risk	53,1	medium	60,6	medium
A13 217	49,4	medium risk	49,4	medium risk	55,6	medium	60,6	medium
A13 218	49,4	medium risk	49,4	medium risk	49,4	medium	59,4	medium
A13 219	65,0	medium risk	65,0	medium risk	42,5	medium	50,0	medium
B13 300	76,1	low risk	76,1	low risk	56,3	medium	56,3	medium
B13 301	75,6	low risk	75,6	low risk	51,3	medium	51,3	medium
B13 302	71,7	low risk	71,7	low risk	53,8	medium	53,8	medium
B13 303	68,3	low risk	68,3	low risk	36,3	medium	46,3	medium
B13 304	60,0	medium risk	60,0	medium risk	41,3	medium	48,8	medium
B13 306	56,7	medium risk	56,7	medium risk	51,3	medium	51,3	medium
B13 307	56,1	medium risk	56,1	medium risk	48,8	medium	56,3	medium
B13 308	43,9	medium risk	43,9	medium risk	41,3	medium	41,3	medium
B13 401	67,2	low risk	67,2	low risk	35,0	medium	42,5	medium
B13 402	41,1	medium risk	41,1	medium risk	47,5	medium	60,0	medium
B13 403	46,7	medium risk	46,7	medium risk	38,8	medium	33,8	medium
B13 404	47,2	medium risk	47,2	medium risk	41,3	medium	36,3	medium
B13 405	60,0	medium risk	60,0	medium risk	51,3	medium	46,3	medium
B13 406	73,3	low risk	73,3	low risk	43,8	medium	48,8	medium
C13 501	59,4	medium risk	59,4	medium risk	50,6	medium	50,6	medium
C13 502	56,1	medium risk	56,1	medium risk	75,6	low	72,5	low
C13 503	49,4	medium risk	49,4	medium risk	66,9	medium	63,8	medium
C13 504	53,9	medium risk	53,9	medium risk	68,8	low	63,1	medium
C13 505	77,2	low risk	77,2	low risk	80,0	low	79,4	low
C13 506	71,1	low risk	71,1	low risk	76,3	low	70,6	low
C13 507	40,0	medium risk	40,0	medium risk	46,9	medium	43,8	medium
C13 508	53,9	medium risk	53,9	medium risk	61,3	medium	55,6	medium
C13 509	65,6	medium risk	65,6	medium risk	61,3	medium	60,6	medium
C13 510	54,4	medium risk	54,4	medium risk	41,9	medium	46,3	medium